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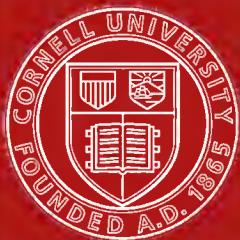
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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE GEOLOGY

OF THE COUNTRY NEAR

YARMOUTH AND LOWESTOFT.

(EXPLANATION OF SHEET 67.)

BY

J. H. BLAKE, F.G.S., Assoc. M. Inst. C.E.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.



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THE GEOLOGY

OF THE COUNTRY NEAR

YARMOUTH AND LOWESTOFT.

(EXPLANATION OF SHEET 67.)

BY

J. H. BLAKE, F.G.S., Assoc. M. INST. C.E.

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P R E F A C E.

The district described in the present Memoir, embracing the area included in Sheet 67, was geologically surveyed by Mr. J. H. Blake. Its chief geological interest and importance arise from the long coast-sections which, by laying bare the strata for many miles, throw light on the structure of the drift-covered interior. The section south of Lowestoft, though it partly runs into the ground shown in the next map to the south (Sheet 49), is all described in the following pages. It exposes the various formations from the Boulder Clay down to the sand and gravel at the base of the Chillesford Series; the section between Lowestoft and Yarmouth displays the succession of deposits from the Post-glacial gravel and sand to the rootlet-bed at the top of the Chillesford Series; while that north of Yarmouth shows Glacial drift appearing from under blown sand. The first two of these lines of coast-section were constantly visited by Mr. Blake during the time that he was stationed at Lowestoft; their details, varying from month to month according to the effects of storms, were carefully noted, and were embodied by him in Sheet 128 of the Horizontal Sections of the Geological Survey.

This Memoir has been written by Mr. Blake, and edited by the District Surveyor, Mr. W. Whitaker, under whose supervision the field-work was carried on. Mr. C. Reid has contributed the details of some borings made by him, together with a list of plants which he has identified from the Forest-bed (p. 92). The other lists of fossils have been revised by Messrs. G. Sharman and E. T. Newton. It may be added that full bibliographies of the geological literature, descriptive of the area embraced in Sheet 67, have already appeared in former Memoirs of the Geological Survey; for Norfolk (by W. Whitaker and H. B. Woodward) in "The Geology of the Country around Norwich" (1881), and for Suffolk (by W. Whitaker) in "The Geology of the Country around Ipswich" (1885).

ARCH. GEIKIE,
Director-General

Geological Survey Office,
Jermyn Street, London,
19th February 1890.

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THE GEOLOGY

OF THE COUNTRY NEAR

YARMOUTH AND LOWESTOFT.

CHAPTER I. INTRODUCTION.

AREA.

THIS Memoir is descriptive of the country represented in the two parts of Sheet 67, with about 2 square miles in the adjoining sheet to the south (49, N.), which small tract is around Kessingland, and naturally belongs to the district to the north rather than to that to the south. The whole area to be described is about 135 square miles, comprising a tract of country in the most eastern part of England, partly in the county of Norfolk and partly in that of Suffolk. It extends along the coast from the village of Waxham to the north, to that of Kessingland to the south; and westward to the villages of Worlingham, Aldeby, Burgh St. Margarets, Rollesby, &c., in a line from south to north, and includes the important sea-ports and watering-places of Great Yarmouth (or as it will be called Yarmouth) and Lowestoft.

RIVERS.

The principal rivers that flow through the district are the *Yare*, the *Bure*, and the *Waveney*, which together drain an area of about 1,200 square miles. The *Yare* and *Waveney* unite at a spot known as Burgh Flats, westward of Burgh (Castle) Church; then, thus conjoined, enter Breydon Water on the western side, and continue their course in a north-easterly direction to the eastern side, where, at a distance of little more than $3\frac{1}{2}$ miles from their confluence, they are joined by the *Bure*. The combined waters of the three rivers then flow southwards, through Yarmouth Haven, a little more than $2\frac{1}{2}$ miles, to their common outlet to the sea at Gorleston.

The *Yare* drains an area of about 529 square miles. It enters the district westward of Chedgrave Marshes, south of Reedham Mills, and flows in a north-easterly direction to Burgh Flats, and so on to the sea at Gorleston as above described. Its surface-fall from Foundry Bridge, Norwich, to the sea at Yarmouth Haven at low-water, has been estimated to be not more than 2 inches per mile.

The *Bure* drains an area of about 337 square miles. It enters the district south of Herringby, a quarter of a mile N.W. of 7 Mile House, situated north of "the New Road" between Acle and Yarmouth. It flows in an easterly direction to 2 Mile House, where it turns southwards and unites with the confluent rivers, the *Yare* and *Waveney*, on the eastern side of Breydon Water. The fall of the *Bure* between Wroxham Bridge and Yarmouth is presumed to be about 2 inches per mile.

The *Waveney* drains an area of about 334 square miles. It enters the district in the marshes south of Aldeby, and continues its course eastwards round the promontory of Burgh St. Peter, then turns in a north-westerly direction and follows a tortuous course through the alluvium or marsh-land south of Somerleyton, Herringfleet, and Fritton, and finally turns northwards and winds its way through the marshes westward of Belton, and so on to Burgh Flats, where it unites with the Yare. The fall of the *Waveney* from Beccles Bridge to Yarmouth, has been estimated to be about the same as that of the other rivers, 2 inches per mile.

Besides the above more important rivers, there are smaller streams in the district. (1.) The *Hundred Stream* (so-called, apparently, because it forms the divisional-line between the Hundred of Happing and that of West Flegg), or river Thurne as it was formerly and is now sometimes called, which is a tributary of the Bure. That portion of it which appears in the area under consideration, flows through the alluvium or marsh-land from near the coast (where it formerly had an outlet to the sea), in a south-westerly direction S. of Horsey and past Martham Broad and Heigham Sound, where it leaves the district and eventually falls into the Bure. (2.) *Muck Fleet*, which drains Filby, Rollesby, and Ormesby Broads, and falls into the Bure nearly a mile S.E. of Acle Bridge. (3.) The other stream (apparently nameless) forms the southern boundary of the area, and first occurs S. of Ellough Hall, then flows in an easterly direction S. of Mutford and Rushmere Halls, turns, and follows a south-easterly course S. of Kessingland to its outlet to the sea at Benacre Sluice (in Map 49, N.).

The following particulars are taken from a Report made by Sir JOHN HAWKSHAW in 1879:—

The effect of the tide is felt up the *Yare* as far as the New Mills at Norwich, a distance of 29 miles from the Pier-head at Great Yarmouth; up the *Bure* at least as far as Wroxham Bridge, a distance of 25 miles; and up the *Waveney* as far as Ship Meadow Lock ($2\frac{3}{4}$ miles above Beccles Bridge), a distance of 27 miles.

The range of tide at Norwich, at the Foundry Bridge, is about 15 inches; on the Bure at Wroxham Bridge less than 14 inches; and on the *Waveney* at Beccles Bridge about 14 inches. With a range of tide* at Yarmouth Pier of $4\frac{1}{2}$ feet, there would be a range of tide at Yarmouth Bridge ($2\frac{1}{2}$ miles from the Harbour-mouth) of 2 feet 4 inches, and at the upper end of Breydon Water of only 1 foot 8 inches.

The banks along the tidal parts of the rivers are generally low, and often insufficient. In many places there are no embankments, and the water often covers large tracts of marshy ground, or spreads out into extensive shallow lakes or "broads." An obvious improvement to the drainage might at once be effected and at no great cost, by discharging, through an outlet at Mutford, a part of the flood-waters of the *Waveney* into the sea through Lake Lothing, at Lowestoft. "For proof of this," says SIR JOHN HAWKSHAW, "it is enough to state that while the fall from Beccles to Yarmouth is about two inches per mile, the fall to low-water at Lake Lothing would be about five inches per mile."†

* At Yarmouth Road the tide rises 6 feet at Springs, $4\frac{1}{2}$ feet at Neaps.

† The *Yarmouth Independent*, 14 June 1879.

BROADS OR LAKES.

The Broads lie chiefly in the south-eastern part of Norfolk and in an adjoining small part of Suffolk; and "an ideal triangle traced upon the map, having for its angles Norwich, Lowestoft, and Happisburgh, will comprise the principal part of them They are of all dimensions, from the puny pool, overgrown with weeds, called here provincially a "pulk," to the wide-expanded lake."*

The word Broad (derived from the Anglo-Saxon *Bredan*, to spread out or broaden) is used, in Norfolk and Suffolk, for those parts of a river that expand to a great width, forming a sort of lake.

These Broads abound in the alluvial plains through which the Bure, Yare, and Waveney, and their tributaries, more or less sluggishly meander, and are all connected by water-courses with these rivers, either directly, or indirectly through their tributary-streams. With the exception of Breydon Water, the Broads are not in the direct course of the main rivers, but occur here and there on either side, at distances varying from a few yards to a few miles. There are some, however, that occur in the direct course of the tributary-streams, and thus literally fulfil their designation as being a broadening of the stream, which some sheets of water called "Broads," in their present position do not.

"It is somewhat difficult," says MR. G. C. DAVIES, "to analyse the charm which the "Broad" District of Norfolk and Suffolk has for those who have once made its acquaintance in the only way in which an intimate knowledge of it can be gained. In a journey through it by rail, you see nothing but its flatness; walk along its roads, you see the dulllest side of it; but take to its water-highways, and the glamour of it steals over you, if you have aught of the love of nature, the angler, or the artist in you."

"The slowly-moving water is more like a living companion than any other inanimate thing can be. Houses are few and far between, oftentimes within the circle of your sight there is neither house nor man visible. A grey church tower, a windmill, or the dark brown sail of a wherry in the distance breaks the sense of utter loneliness, but the scene is wild enough to enchain the imagination of many. Long miles of sinuous gleaming river, marshes gay with innumerable flowering plants, wide sheets of water bordered with swaying reeds; yachts or wherries, boats, fish, fowl and rare birds and plants, and exquisite little bits to paint and sketch."†

The following is a graphic picture of the life of a Broad-man and his round of occupation, as given by the late REV. R. LUBBOCK, Rector of Eccles:—

"When I first visited the Broads, I found here and there an occupant, squatted down, as the Americans would call it, on the verge of a pool, who relied almost entirely on shooting and fishing for the support of himself and family, and lived in a truly primitive manner. I particularly remember one hero of this description. "Our broad," as he always called the extensive pool by which his cottage stood, was his microcosm—his world; the islands in it were his gardens of the Hesperides,—its opposite extremity his *ultima Thule*. Wherever his thoughts wandered, they could not get beyond the circle of his bordered lake; indeed, I never knew them aberrant but once, when he informed me, with a doubting air, that he had sent his wife and his two

* Lubbock's "Fauna of Norfolk," pp. 78, 79.

† The Handbook to the Rivers and Broads of Norfolk and Suffolk, pp. 9, 10. London, 1882.

eldest children to a fair at a country village two miles off, that their ideas might expand by travel: as he sagely observed, they had never been away from "our broad." I went into his house at the dinner hour, and found the whole party going to fall to most thankfully upon a roasted Herring Gull, killed of course on "our broad." His life presented no vicissitudes but an alternation of marsh employment. In winter, after his day's reed-cutting, he might be regularly found posted at nightfall waiting for the flight of fowl, or paddling after them on the open water. With the first warm days of February he launched his fleet of trimmers, pike finding a ready sale at his own door to those who bought them to sell again in the Norwich market. As soon as the pike had spawned, and were out of season, the eels began to occupy his attention, and lapwings' eggs to be diligently sought for. In the end of April, the island in his watery domain was frequently visited for the sake of shooping ruffs which resorted thither, on their first arrival. As the days grew longer and hotter, he might be found searching, in some smaller pools near his house, for the shoals of tench as they commenced spawning. Yet a little longer, and he began marsh mowing, — his gun always laid ready upon his coat, in case flappers should be met with. By the middle of August, teal came to a wet corner near his cottage, snipes began to arrive, and he was often called upon to exercise his vocal powers on the curlews that passed to and fro. By the end of September, good snipe shooting was generally to be met with in his neighbourhood; and his accurate knowledge of the marshes, his unassuming good humour, and zeal in providing sport for those who employed him, made him very much sought after as a sporting guide, by snipe shots and fishermen; and his knowledge of the habits of different birds enabled him to give useful information to those who collected them.*

"There are men," says MR. T. SOUTHWELL, in the Introduction to the work above quoted, "who even now continue to lead an almost similar life, and great is their attachment to the freedom and excitement of such an occupation."

The method of formation and origin of the Broad's will be treated of further on, after the geological formations composing their basins and by which they are surrounded have been described.

The principal Broad's connected with the rivers Bure, Yare, and Waveney, are about 34 in number; 25 of which are in the district drained by the Bure. They cover an area of about 4,316 acres, inclusive of Lake Lothing and Breydon Water, which are tidal; and they vary in size from about 11 acres to 1,200.

The following occur in the district under consideration†:—

		ACRES.
River Bure	{ Horsey Meer - - - -	130·6†
	{ Martham Broad - - - -	115·5†
	{ Heigham Sound - - - -	150·2
	{ Ormesby, Rollesby, and Filby Broad - - - -	464·9†
River Yare	- Breydon Water (tidal) - - - -	1,200·0
River Waveney	{ Fritton Decoy - - - -	157·0†
	{ Flixton Decoy - - - -	12·8†
	{ Oulton Broad - - - -	99·0†
	{ Lake Lothing (tidal) - - - -	150·0
		<hr/> 2,480·0

* LUBBOCK'S Fauna of Norfolk, New Edition, pp. 129, 130. *Norwich and London*, 1879. Edited by T. SOUTHWELL.

† The other Broad's are mentioned in the Geological Survey Memoir on the Country around Norwich; by H. B. WOODWARD, p. 4 (1882). See also *Trans. Norfolk Nat. Soc.*, vol. iii., p. 448.

‡ Areas given by MR. R. B. GRANTHAM, *Quart. Journ. Geol. Soc.*, vol. xxv. p. 258 (1869).

Horsey Meer, Martham Broad, and Heigham Sound are drained by the Hundred Stream or River Thurne into the Bure; and Ormesby, Rollesby, and Filby Broads (or Broad, as it is but one sheet of water with two roads or causeways across) by an appropriately termed channel called Muck Fleet, for it is said to be both fleet and dirty.

Fritton Decoy, Flixton Decoy, and Oulton Broad, are each connected with the river Waveney by a separate dyke or stream.

GEOLOGICAL FORMATIONS.

The following are the formations shown on the Geological Survey Maps treated of in this Memoir, with the exception of the Eocene and the Cretaceous deposits, which do not come up to the surface (but have been proved, by a boring at Yarmouth, to underlie a portion, and probably the whole, of the area) and of the Crag:—

Recent	-	{	Blown Sand.
			Beach-sand and Shingle.
			Alluvium.
			Plateau Gravel, Sand, and Loam.
Glacial Drift	-	{	Boulder Clay (Upper Glacial of Wood).
			Sand (Middle Glacial of Wood).
			Loam, with Boulders (Lower Glacial of Wood).
			Pebbly Series.
Pliocene	{	Forest Bed Series	{
			Freshwater Beds.
			Rootlet-bed, etc. (Forest-bed).
			Gravel and Sand, with Mammalian remains.
			Chillesford Beds. Laminated Clay and Sand.
			? Crag (in a boring, see p. 86).
Eocene	-	-	{
			London Clay.
			Reading Beds.
Cretaceous	-	-	- Chalk.

CHAPTER II. CRETACEOUS AND EOCENE BEDS.

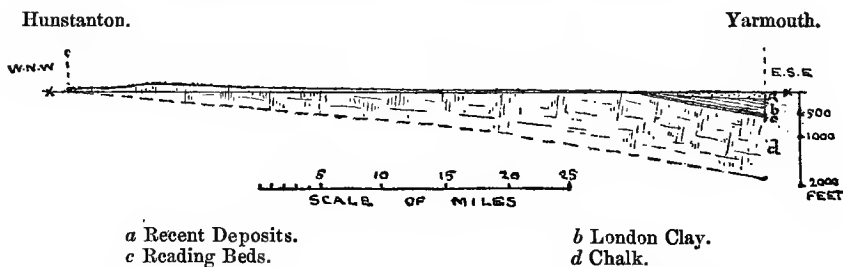
CHALK.

This formation underlies Yarmouth at a depth of 527 feet, at Sir E. Lacon and Co.'s Brewery, which is 20 feet above Ordnance Datum (*see* well-section, p. 82).

The Chalk met with was white and very soft, and contained many black flints. Only a few small pieces of it have been preserved: a fragment of one of these was kindly given to me at the brewery by MR. NIGHTINGALE, and submitted to DR. WALLICH, who, after careful examination, stated, "My object was not to search for novelties in the way of Foraminifera and Spongespicules, &c., but to determine, if possible, whether there was any general difference between the lithological constitution of this chalk and that met with in the surrounding pits. I could detect none."*

From sections drawn and from calculations made, I think it is probable that the Chalk underlying Yarmouth may be 1,300 feet in thickness, and may possibly contain higher beds than occur elsewhere in Norfolk. That thickness would make the base of the Chalk under Yarmouth 1,806 feet beneath the sea-level, and, consequently, there would possibly be a total rise of that amount (or a little more) at Hunstanton (distant about $56\frac{1}{2}$ miles), where the base of the Chalk comes up above the sea-level, as shown in the fine cliff-section. Taking an inclined plane for the base

FIG. 1.

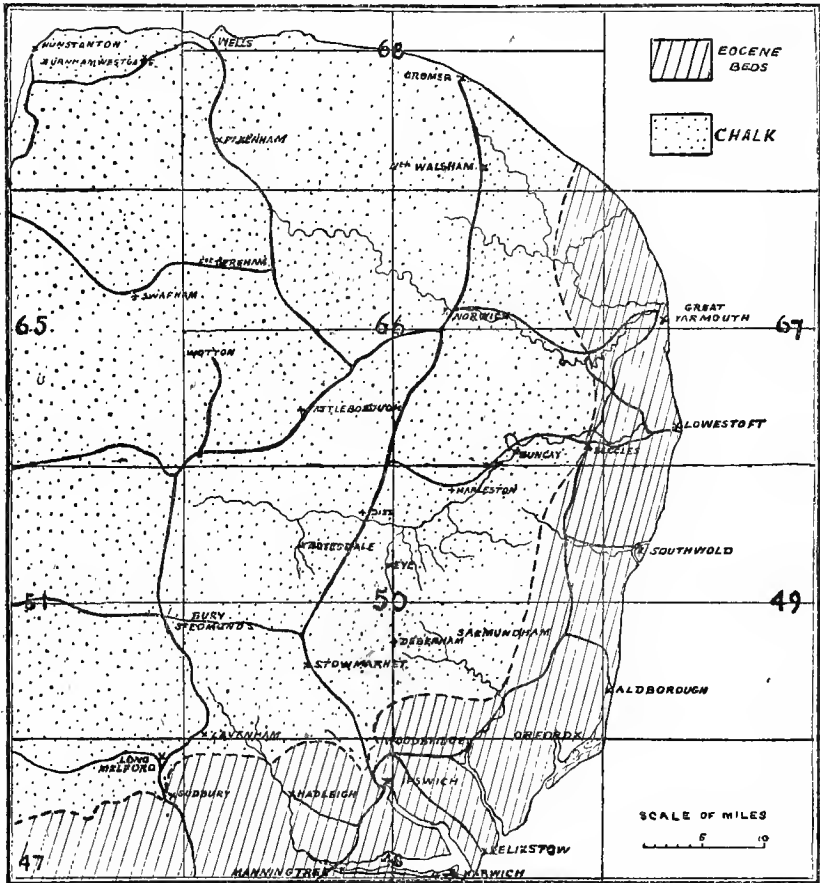
Diagram-Section from Hunstanton to Yarmouth.

of the Chalk between Hunstanton and Yarmouth, this total rise of 1,806 feet would represent a rise of 32 feet per mile, which is equivalent to an inclination of 1 in 143, or an angle of only $\frac{1}{3}$ rd of a degree. If along a portion of this line, commencing at Yarmouth and continuing north-westwards, the plane of the top of the Chalk is parallel with its base, this plane would come to the surface of the ground on the east of Wroxham where

* In a letter to the author, dated Feb. 15th, 1881.

FIG. 2.

Map showing the probable position of the Boundary-line of the Eocene Beds, beneath the Drift, &c.



The numbers (47 to 68) are those of the sheets of the Geological Survey Map. The thick lines are for the more important railways.

chalk is known to be at or near the surface.* It is quite possible, therefore, that between Yarmouth and Wroxham, the Chalk may average about 1,300 feet in thickness; and no great amount of it, if any, may have been denuded; the greater portion of it along this distance probably being covered with Eocene Beds. That is not the case, however, between Wroxham, where the Chalk comes up to the surface of the ground, and Hunstanton; inasmuch as between these two places, there has obviously been an immense amount of denudation of the Chalk. A right-angled triangle, having its apex E. of Wroxham, its base at Hunstanton, from about 1,100 feet to 1,200 feet in height, and its hypotenuse about 45 miles in length would apparently represent the sectional area of the great triangular mass of Chalk that has here been planed off, and that, at a not very remote period, geologically speaking.

The deep Boring at Messrs. Colman's Carrow Works at Norwich is stated to have pierced about 12 feet of Alluvium, then 1,140 feet of Chalk, and then through 6 feet of Upper Greensand into 38 feet of Gault. The level of the ground at the site of the well is 15 feet† above mean sea-level; consequently, according to these figures, the base of the Chalk at Norwich would be 1,137 feet beneath the sea-level. Taking the base of the Chalk at Yarmouth at 1,806 feet, this would give a total rise at Norwich of 669 feet, or 38 feet per mile, equivalent to a gradient or inclination of about 1 in 139, or an angle of less than $\frac{1}{2}$ and more than $\frac{1}{3}$ rd of a degree.

READING BEDS.

This formation was met with, at a depth of 480 feet, in the Yarmouth well-boring, as described at p. 82; but has not been proved elsewhere in the district. It is apparently 46 feet thick, and consists mostly of grey clay and green sand.

LONDON CLAY.

This deposit occurs under Yarmouth. Although the boring here was made in 1840, the true nature of the deposits that had been penetrated was neither thoroughly understood nor made known until 20 years afterwards, when PROFESSOR PRESTWICH read a paper to the Geological Society "On the Presence of the London Clay in Norfolk, as proved by a Well-boring at Yarmouth," in which he said :—

"The northward extension of the London Clay has hitherto been considered to have its limits in the southern part of Suffolk. Its lower beds outcrop near Ipswich; at Harwich it is only 23 feet thick; and, as from thence

* See Sheet 66 N.E. of the Geological Survey Map.

† Ordnance level 15.1 feet; kindly supplied by the Director General of the Ordnance Survey.

to Bawdsey near Orford, the rise is to the northward, the impression is given that the Eocene series ends under the Coralline Crag somewhere about Orford or Aldborough, and that further north the Pleiocene series reposes directly on the Chalk; such being in fact their superposition throughout North Suffolk and Norfolk wherever the base of that series is visible.

"An exception, however, to this order has been proved by a well-boring at Great Yarmouth. . ."

"Specimens of the boring were taken with great care at every 10 feet or less of depth, and were duly noted and preserved; whilst a well-executed coloured section of the well records the general features. . ."

"At the depth of 170 feet the beds change so suddenly, and the hand-specimen, with its small light-brown concretion, is so like an ordinary specimen of London Clay, that I at once noted its resemblance, but without at all suspecting the London Clay to be there. When, however, I passed from specimen to specimen with like or very similar characters through a thickness of above 100 feet, I began to suspect that it was a mass of London Clay; and the examination of the remaining specimens strengthened that conviction. There were, it is true, no fossils (that, however, often happens in borings of the London Clay in the London district itself); but the characters of the beds were so uniform and so closely resembled the ordinary London Clay, and the small calcareous and phosphatic nodular concretions were so identical with specimens common in the London Clay of Essex and Kent,—and the whole is underlain by a seam of septaria, so usual in the Essex wells,—and these by a series of beds of green sand and clay with lignite, so characteristic of the beds between the London Clay and the Chalk (although they here present a modified type), that I have not the slightest doubt of this being a mass of true Lower Eocene strata *in situ*."

"Such a circumstance renders it probable that a bed of variable thickness of London Clay may extend beneath the Crag between Orford and Yarmouth, and may possibly range as far north as Mundesley or Bacton."*

MR. GUNN says "the labourers employed were of opinion that London Clay was brought up by the boring apparatus, as they had been engaged in a similar work in that deposit; but their opinion was disregarded, as this clay was not supposed to extend beyond Aldborough."†

The above inference of PROF. PRESTWICH'S, expressed so long ago as the year 1860, has been confirmed by all the borings that have since been made in the eastern part of Suffolk, as described in various Geological Survey Memoirs, which prove the presence of the London Clay underground along the coast.‡

I know of no other deep borings north of Southwold in this eastern part of Norfolk and Suffolk, except the two that were made for Beccles Waterworks, where Chalk was reached at a depth of 157 feet. From sections I have constructed, one would have anticipated that the Reading Beds, which were met with in the Yarmouth boring, would have been found at Beccles, but not necessarily any portion of the London Clay, which probably would not extend so far.

MR. W. M. CROWFOOT, of Beccles, however, to whom we are indebted for the details of these well-sections,§ has recently written to me to state that he had conferred with MR. E. T.

* *Quart. Journ. Geol. Soc.*, vol. xvi., pp. 449-452.

† *White's History, Gazetteer, etc., of Norfolk.* Ed. 4, p. 90 (1883).

‡ The Geology of the Country around Ipswich, &c., 1885. The Geology of the Country around Aldborough, &c., 1886. The Geology of the Country around Halesworth, &c., 1887. The Geology of Southwold, &c., 1887.

§ See The Geology of the Country around Norwich, by H. B. WOODWARD, p. 156, and table opposite, *Geological Survey Memoir*.

DOWSON, who saw the materials brought up, and that they agreed in thinking that if any beds similar to those in the Yarmouth well had been pierced they must have observed them. And, moreover, they think that MR. QUILL, the engineer, would also have done so; as he noted all the variations in the beds as they were reached in succession. Under these circumstances, both MR. CROWFOOT and MR. DOWSON are of opinion that there was no alteration in the material of the strata composing the last 20 feet of beds before the Chalk was reached.

The limit of the Eocene beds, therefore, in the direction of Beccles from the coast cannot be given with certainty; and, in fact, only approximations can be given of their extent from Yarmouth towards Norwich, Wroxham, Bacton, and other places; inasmuch as there are no deep borings to prove their position.

From calculations based upon all the available data, a more or less curved line commencing from the coast near Happisburgh and passing through or near the following places, would give the probable limit of the Reading Beds:—Stalham, Catfield, Ludham, Acle, Halvergate, Beccles and westward of Halesworth. Possibly though the formation may extend further westward, on the north.

The London Clay would necessarily not extend so far as this, but its edge would form a more or less concentric line within it, the distance averaging from about 2 to 3 miles, varying according to the slope of the basin and the thickness of the Reading Beds.

Although the great thickness of Eocene beds mentioned was so long since known to be present beneath this eastern part of England, it has generally been ignored on most geological maps, and frequently also in descriptions given of the Eocene beds in England. MR. WHITAKER alluded to this error in his Presidential address to the Norwich Geological Society in 1883.*

The thickness of the London Clay at Yarmouth has been stated to be 310 feet; but that does not represent the total thickness of the London Clay in the district, inasmuch as the site of the boring is near the middle part of a former estuary, where a considerable thickness of London Clay has evidently been scoured out, and the channel, the base of which is 150 feet beneath the present sea-level, has been filled in with estuarine and other alluvial deposits, now forming the extensive tract of marsh-land in the vicinity of Yarmouth. So, it would be reasonable to infer, that the greatest thickness of the London Clay in this district, the most eastern part of England, would be on the northern and southern sides of this excavated hollow, where it might range from about 400 to 430 feet, and it may be more under the North Sea. The actual thickness would necessarily depend upon the thickness of the Pliocene or other beds, that may intervene between the base of the Drift-deposits and the London Clay. The estimate given allows from 30 to 60 feet for these, which is pro-

* *Proc. Norwich Geol. Soc.*, part viii., p. 293.

bably a sufficiently liberal allowance, inasmuch as the combined thickness of the Pliocene Beds and the overlying Pebbly Sand (Bure Valley Beds) between the Lower Boulder Clay and the Chalk, in the neighbourhood of Norwich, is nowhere known to be more than about 30 feet. [The Southwold boring, however, made since the above was written, points to a great thickness of Crag, so that it would hardly be safe to take so low an estimate.—W. W.]

The occurrence of some small shells in a Crag-pit at Bramerton, which were probably derived from Upper Eocene or Oligocene beds, has been mentioned by the late MR. S. V. WOOD in his "Second Supplement to the Crag Mollusca." This pit is S. of the river Yare, about $4\frac{1}{2}$ miles S.E. by E. of Norwich, and only from a mile to two miles westward from where I should anticipate the Eocene beds would be present, beneath both the surface of the ground and the sea-level.

In the Supplement referred to, Mr. WOOD says: "Mr. Jas. Reeve, of the Norwich Museum, was good enough to send me a quantity of small shells, which he had extracted from the sand of the Bramerton Crag Pit. These consisted for the most part of specimens of species already figured and described, but among them were two or three which appear to me to be quite new to the Crag, if not, indeed, undescribed from any formation. These specimens are all more or less worn and imperfect, a character which is not usual with the specimens of species belonging to any horizon of the Crag in Norfolk; and I feel little doubt that they are not shells which lived in the Crag waters, but are derivatives from some other formation. As they approach species figured in Dr. Speyer's work from the Oligocene of Cassel, in Germany, nearer than they do to any others that I can find figured and described, I suspect that they have been introduced from some Upper Eocene or Oligocene formation in North-Eastern Norfolk, through which a stream flowed which discharged into the estuary of the Fluvio-marine Crag. The probability of such a thing is strengthened by the circumstance that the chalk disappears below the water-line of the country immediately east of the Bramerton Crag Pit, and by the Lower Eocene having been pierced at Yarmouth and found to extend to a depth of 526 feet below the sea-level." *

The specimens in question are preserved in the Norwich Museum, and are fully described by Mr. WOOD, and thus named by him:—*Cerithium derivatum*, S. Wood (two specimens); and *Odostomia? derivata*, S. Wood (several specimens). Besides these there was a single specimen of an *Odostomia*, sp.? a fragment of a small bivalve resembling *Siliquaria parva*, Speyer., and an imperfect specimen of a minute *Actæon*, resembling *A. Philippii*, Koch and Wiechmann.

Another specimen obtained by Mr. James Reeve from the same Crag-pit at Bramerton has been figured in the "Third Supplement to the Crag Mollusca" (1882). Mr. WOOD has named it *Odostomia Reevei*, and his son, who edited the Supplement, says: "The specimen figured is probably one which has been carried into the fluvio-marine Crag from the same bed as that which supplied *Cerithium derivatum* and *Odostomia derivata*."

* Second Supplement to the Crag Mollusca. *Palæontograph. Soc.*, p. 40. See also C. Reid, On Norfolk Amber. *Trans. Norfolk Nat. Soc.*, vol. iii., p. 601, and vol. iv., p. 247. The depth is 506 feet below the sea-level, and 526 feet below the surface of the ground.

CHAPTER III. PLIOCENE.

GENERAL REMARKS.

The beds included under the term Pliocene in this district come to the surface rarely, and rise little above the sea-level. They are only to be seen in the cliff and on the foreshore at Corton, and along the coast between Pakefield and Kessingland; and, here and there, south of Mutford and Kessingland, bordering the Alluvium through which meanders the stream that finds its outlet at Benacre Sluice.

Although so seldom seen, they are nevertheless of considerable geological interest; representing, as they do, that period immediately preceding the so-called "Great Ice Age," when all the deposits of the Glacial Drift, which form so large a portion of East Anglia, were accumulated, in the order of superposition herein mentioned, but obviously not at their present altitude with respect to the sea-level.

It is difficult to realise, with any approach to exactitude, the configuration of the land relatively to the sea, in these Pliocene times; although these were not so very remote, geologically speaking. Some idea may be formed by an attempt at mental reconstruction; when the difficulties presaged, however, will soon become apparent. For instance, all those heterogeneous Drift-deposits must of necessity be removed; the amount of erosion, and consequently its concomitant deposition, having been great during this remarkable, but, I am inclined to think, comparatively brief, period. This mental process of pulling-down and building-up, so to speak, may be left for the intelligent and curious reader to pursue; as such speculations would not only carry me far and wide, away from the district; but would be foreign to the purposes of this Memoir.

Although the Pliocene deposits in this neighbourhood admit in places of being divided into the divisions above enumerated, these are nevertheless most intimately connected; and the uppermost two divisions are, as is usually the case, but a few feet in thickness. It is very seldom, however, that any portion of the mammaliferous gravel and sand, is exposed; therefore the combined thickness of the divisions in this district is not known.

[It should be noted that the classification and arrangement now used has been adopted in deference to the opinions of various colleagues. The author still holds to the views expressed in his published cliff-section,* and thinks that the mammaliferous gravel is older than the Chillesford Clay; so that, instead of

* Horizontal Sections, Sheet 128, and the Explanation thereto (1884).

classing it with the Forest-bed Series, he takes it rather to represent the Norwich Crag. One objection to this is its freedom from evidence of marine origin, with which evidence the Crag teems. Another is the occurrence of Mammalia of Forest Bed species, not of Crag species. His views are now given in his own words.—W. W.]

The mammaliferous deposit described (pp. 15-17), I think, occupies the same relative position, as the Sands that underlie the laminated micaceous clays in the neighbourhood of Chillesford and elsewhere, and which PROF. PRESTWICH described as "Sands" in 1849, but which he called "Chillesford Sands" in 1870, in contradistinction to the term "Chillesford Clay" which he applied to the overlying laminated clays. In the text of his paper,* in 1870, he included both sub-divisions under the general term "Chillesford Beds," and sometimes under that of "Chillesford Series." The sub-division "Chillesford Sands," PROF. PRESTWICH and several other geologists have considered to be equivalent to the upper part of the Norwich Crag, a conclusion with which I concur. They pass up without break into the overlying laminated clays and sands (Chillesford Clay) both in Norfolk and Suffolk, and mammalian remains have been found in them in various places. Consequently, it seems to me that some of this mammaliferous gravel and sand, from its position beneath the Rootlet-bed, and what I take to be Chillesford Clay, may possibly be of the age of the Norwich Crag.

CHILLESFORD BEDS.

General Remarks.

These beds are usually called Chillesford Clay, from the place where they were first studied and on account of their clayey character; but they really consist of alternations of thin bands of grey clay and white and brown sand; both being very micaceous, or generally so, which is one of their chief characteristics. Sometimes the clay predominates, and sometimes the sand; occasionally the one almost to the exclusion of the other. Notwithstanding this, however, their character is generally so well-marked, and they occupy, in my opinion, such a definite horizon throughout Norfolk and Suffolk, overlying the Crag and underlying the Drift, that few mistakes can be made respecting their identification.

On the Coast at Kessingland and Pakefield.

In this district, a characteristic section of these beds can generally be seen in the lower part of the cliff at Pakefield Lighthouse Gap, S. of Lowestoft.† They there consist of alternations of laminated grey clay, and white and brown sand, the

* *Quart. Journ. Geol. Soc.*, vol. xxvii., p. 453.

† See Horizontal Section, Sheet 128.

layers varying from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch in thickness, the total mass exhibited averaging from 11 to 12 feet in thickness. They incline northwards, and gradually disappear beneath the beach, occurring at the base or lower part of the cliff nearly as far as the second Gap.

I have seen a continuous section of them from the first basin-shaped hollow S. of Pakefield Lighthouse Gap, northwards for a distance of 1,100 yards. It occurred after a gale, when the beach-sand, which usually covers a large portion of them east of the Gap, had been scoured out by the sea, and thus disclosed the beds. They presented the same character throughout, consisting of laminated clays with partings or thin layers of sand. During five years' residence on the Norfolk and Suffolk Coast, I only once saw this portion of the shore so much uncovered. The sight was a remarkable one, for instead of there being a soft and beautiful buff beach-sand to walk upon, as is usually the case, there was a shelving shore of dark grey slippery clay. The sight reminded me of the fore-shore on the southern side of the Bristol Channel, near Watchet, where the laminated beds of the Lower Lias crop out; but with this difference, that there the beds, of much older age, are indurated into shales, and embellished with immense quantities of large iridescent Ammonites, glistening in their golden and variegated colours as beautifully as anything of the kind to be seen in antique glass. In these sombre Chillesford Beds there was nothing of the sort to be seen, and not a single fossil could be found in them. Other sections can be seen on the coast toward Kessingland. The Chillesford Beds there occur beneath the Rootlet-bed at the base of the cliff and on the fore-shore, but where they lie at a very low level, it is only on rare occasions, when there has been a scouring of the beach, that good sections are exposed. They rise up, however, to a higher level opposite to and S. of the Flag-staff at Kessingland, where they can be seen in the cliff, provided they are not obscured by blown sand, which is often the case. Here and there white and buff pebbly sand, containing seams and patches of grey clay, occurs between the characteristic laminated clays of the Chillesford Beds and the overlying Rootlet-bed.

At the extreme southern end of the cliff, near the road that leads to the village of Kessingland, there is less sand in the laminated clays of the Chillesford Beds, which are, moreover, contorted in places, and contain ferruginous concretions. In these and in other respects, they resemble those to be seen at the northern end of Covehithe Cliff, $2\frac{1}{2}$ miles further south, where fine sections of these Chillesford Beds are to be seen, as well as in the next cliff still further south, at Easton Bavent.*

On the Coast at Corton.

The only other place where these Chillesford Beds have been observed on the coast in the district, is on the shore at Corton,

* See "The Geology of Southwold, etc.," 1887.

nearly half-a-mile N. of Corton Gap. They occupy a similar position here, beneath the Rootlet-bed, as between Pakefield and Kessingland; but, as they occur at an extremely low level, they are scarcely ever to be seen, inasmuch as they are nearly always covered by beach-sand and shingle. On an exceedingly favourable occasion, when there had been a complete scour of the whole beach over a large area, I saw and measured so much of the beds as is depicted on the published Section of this Cliff. They consisted of alternations of well-stratified grey and brown clay and brown sand, and were ferruginous in places.

Local Details, Inland.

Kessingland.—In a well on low ground the laminated beds were met with (see p. 83).

In a sand-pit half-a-mile S.S.W. of Kessingland Church, on the northern side of the road, very finely stratified micaceous grey clay, brown loam and sand (Chillesford Beds), more or less laminated, underlying buff sand, were dug into to a depth of 3 feet, so that their total thickness was not shown.

Mutford.—About 200 yards E. of Mutford Hall, a pit in the little wood on the eastern side of the marshes exposed the following section:—

	Feet.
Buff sand, false-bedded in places	4½
Pebbly Sand { Orange-coloured sand, indurated and false-bedded in places, with a seam or patch of coarse shingle, containing ferruginous concretions	4½
Chillesford Beds. Alternations of laminated grey clay and brown sand	3+

The top of the Chillesford Beds was 9 feet above the bottom of the pit, but the section was much obscured by talus, and only the upper 3 feet was clearly shown.

Ellough.—About three quarters of a mile W.S.W. of Hulver Bridge, in a pond just south of the road and north of the farmhouse, there was exposed a little grey clay and sand interstratified, evidently belonging to the Chillesford Series, but too small a patch to map.

GRAVEL AND SAND, WITH MAMMALIAN REMAINS [FOREST-BED SERIES].

On the Coast at Kessingland and Pakefield.

This deposit consists of well-stratified gravel, with occasional seams of grey clay and sand, is ferruginous and indurated in places, and contains numerous mammalian remains. It has been seen in a few places along the coast at Kessingland and Pakefield, when the beach-sand and shingle which usually cover it have been removed by the scouring action of the sea, from the base of the cliff to low-water mark (a distance of about 30 to 40 yards), and for a continuous length along the shore of about 50 to 100 yards or more. It is very seldom, however, that it is so exposed; but when it is, numerous mammalian remains are generally procurable by anybody who may be fortunate enough to be on the spot. Whilst it is thus uncovered, the sea breaks up the

beds, and scatters the bones and other mammalian remains along the shore; sometimes into some sheltered nook amongst the masses of fallen Boulder Clay, or into some hollow, made by the waves in the clayey rootlet-bed, at the foot of the cliff. Here the bones remain secure, perhaps on a soft bed of sand (which mostly forms the beach), for several days; until, may be, some collector visits the spot and secures his prize.

This destructive process, however, generally only continues for two or three days; for, with a change of wind, subsidence of a gale, or fall of the tide, a change takes place and the beds (or what remains of them) are again covered up by beach-sand and shingle, which effectually protects them from further ravages of the sea, until at some future time the process is again repeated. It is on these occasions, when the connection of the beds cropping out along the fore-shore with those that occur in the cliff is so clearly exhibited, that their relative age can be proved by direct superposition. The few patches that came under my notice at different times, whilst geologically mapping the district, are shown on the large detailed section of these cliffs.*

On different occasions mammalian remains were obtained from the locality where the irregular patch is shown on the Section beneath the second basin-shaped hollow S. of Pakefield Lighthouse Gap.† Having heard that mammalian remains were frequently found at this spot, one was particularly anxious to see the beds from which they were obtained; but, although constantly on the look-out, several months elapsed before I was fortunate enough to see an exposure of them. At length a gale and high tide occurred, which created a kind of gully and back-water close up against the base of the cliff; and the water, escaping during the ebb-tide, assisted to scour out the beach and reveal so much of the beds as is depicted on the Section. They presented a shelving or step-like appearance on the shore, from the base of the cliff towards ordinary low-water mark; the area exposed measuring 70 yards in length and about 20 yards or more in width. Various bones, etc., of *Bos*, *Cervus verticornis*, *Cervus*, *Elephas antiquus*, *Elephas*, *Equus*, and *Rhinoceros*, procured on different occasions, are now in the Museum of Practical Geology, London.

Many of the specimens were observed in place; I extracted some myself, some were got by men with picks and crow-bars, and several were washed out by the sea. Nature's method of excavation frequently got out the specimens in a better condition than those obtained by human agency.

Another patch of stratified ferruginous gravel and sand, containing mammalian remains, is shown on the Section about 200 yards S. of the second basin-shaped hollow S. of Pakefield Lighthouse Gap. At this spot, a vessel which was cast ashore became a total wreck; but, before it was broken up, a rough sea occurred which scoured out the beach-sand on its northern side, and thus disclosed this mammaliferous deposit. The beds were more or less indurated, and presented a very similar appearance to those above described. Remains of *Bos*, *Cervus Sedgwickii*, *Cervus* and *Elephas* were obtained from them.

No shells were observed in either of these exposures; but it is well known that MR. THOMPSON, of Pakefield, who has done good service in collecting from these beds, obtained a *Fusus contrarius* from this locality; and, from

* See Horizontal Sections, Sheet 128.

† It is also intended to represent the beds in front of, as well as beneath, the basin-shaped hollow.

what he has said (as he has on several occasions spoken to me about it), it is possible that he procured it from near the first patch of ferruginous gravel and sand above described, but probably at a little lower level. This receives corroboration from the following statement made to me by MR. JOHN GUNN, who says: "I was present when Thompson of Pakefield produced the *Fusus contrarius*, which he said he took from the lowest bed at Pakefield. Harmer observed that it was a drifted specimen, and I never saw it again. Thompson says that he knew that two or three similar specimens had been taken from the same place."*

[A boring, made in 1888, has proved the presence of red sand with broken marine shells between the two hollows of gravel. It would seem probable, therefore, that the *Fusus* may have come from this bed.—W. W.]

ROOTLET-BED [FOREST-BED].

General Remarks.

The Rootlet-bed, the top of which in places is an old land-surface, with thousands of rootlets *in place*, has been traced at intervals around the Suffolk and Norfolk Coasts from Kessingland to Weybourn, a distance of nearly 51 miles. It is impossible to say how far it extends inland, as no trace of it has yet been recognised away from the coast. This is due, in a great measure no doubt, to the low level at which it lies. Much of the bed has evidently been eroded, and merely remnants have been left here and there, some of which, however, are of considerable extent, more than a mile in length. These remnants are to be seen in places at the base of the cliffs, beneath the great mass of Drift, and also in places along the fore-shore, when the beach has been scoured out. They occur along a gently undulating line, appearing sometimes above and sometimes below high-water mark.

In this district, there are two places on the coast where this Rootlet-bed can generally be seen; at Kessingland and Pakefield S. of Lowestoft; and at Corton, between Lowestoft and Yarmouth.

On the Coast at Kessingland and Pakefield.

The exposure of the Rootlet-bed at the base of Kessingland and Pakefield Cliff is by far the finest anywhere to be seen. It is delineated on the detailed engraved Section of this Cliff; and in the accompanying Explanation (p. 3) it has been thus described, the remarks in square brackets being added:—

"This remarkable bed consists of unstratified homogeneous greenish-grey clay, containing numerous calcareous concretions ("race"), small flints, mammalian remains, etc. It extends continuously for a distance of a little more than $1\frac{1}{2}$ miles from Kessingland, where it is 4 feet thick, northwards to the *Unio*-

* In a letter dated Jan. 20th, 1885.

bed, near which it measures 10 feet in thickness. Thousands of rootlets, thickly clustered together and in a vertical position as they grew, are to be observed in various places; penetrating the bed sometimes to a depth of 6 feet, and sometimes through the bed into the sands and laminated beds beneath. The rootlets vary from about $\frac{1}{4}$ to $1\frac{1}{2}$ inch in thickness at the surface, and gradually taper away to nothing; they are more or less crumpled, only occasionally forked, and are all very similar in appearance; although they much resemble the rootlets of Fir trees, [but still more, common furze, in my opinion] there is still some uncertainty as to their identification. The upper part of the bed is in places of a brown colour, and of an irregular, loamy, sandy, and ferruginous nature; and is evidently the remains of an old terrestrial surface, the exact geological horizon of which has long been a matter of dispute.”*

“There is less black *Peat* covering the surface of the Rootlet-bed in this section than at Corton. The only place where any considerable quantity has been observed is on the north of Kessingland, commencing at a spot about 460 yards north of the house on the top of the cliff, and continuing northwards for a distance of 150 yards. The black peat and silt that occur there average from about 6 to 12 inches in thickness. Many seeds were observed in places in the silt, and matted reeds and compressed pieces of wood in the peaty matter; one piece measuring 1 foot in length, 4 inches in width, and compressed to 2 inches in depth.”

“More or less associated with the Rootlet-bed is the deposit known as the *Unio*-bed, which underlies the black laminated beds at the southern end of the second basin-shaped hollow situated south of Pakefield Lighthouse Gap. In this hollow, flint-gravel—more or less ferruginous—occurs at the base of the laminated beds at either end, and partly up the curved slopes, where from a thickness of 1 foot 6 inches at the base it gradually thins away to nothing. At the southern end, the gravel contains many specimens of *Unio*, often with their valves united; together with other fresh-water shells, mostly in a fragile condition, but readily identifiable. Many entire shells occur intermixed with specimens which are in a fragmentary state.”

“This fossiliferous gravel not only underlies the upper laminated-beds [of the age possibly of the Pebbly Sand†], but tongues into and underlies some of the unstratified clay of the Rootlet-bed, which latter also contains a few fresh-water shells at this spot. The following species [obtained by myself] from the gravel, have been

* See Presidential Address “On the Age and Relation of the so-called ‘Forest-bed’ of the Norfolk and Suffolk Coast,” by J. H. B., *Proc. Norwich Geol. Soc.*, part v., pp. 137–160 (1881). Also “A sketch of the Geology of Norfolk,” by JOHN GUNN, Ed. 4, Reprint, pp. 14, 16.

† MR. C. REID thinks that these laminated beds form the upper part of the Forest-bed Series.

identified:—*Unio pictorum* (valves united), *Valvata fluviatilis*, *Pisidium astartoides*, &c. [MR. W. M. CROWFOOT, of Beccles, has also obtained the following:—*Cyclas rivicola*, *Pisidium amnicum*, *Paludina contecta*, *Helix* sp.] A tooth and a vertebra of *Cervus* were also obtained from the shelly gravel on the curved slope at this end. No fossils were observed at the northern end, where the deposits rest against the sharply denuded edges of the Chillesford Beds.”

The denudation that took place in certain parts of East Anglia, previously to the deposition of the “Middle Glacial” sands, and which destroyed so much of the Stony Loam or Lower Boulder Clay (as shown in the cliff at Corton, and in many inland pit-sections), apparently removed a portion of the terrestrial or weathered surface of the Rootlet-bed; as in places the Glacial sands rest directly upon the greenish-grey clay of the Rootlet-bed, without the intervention of the weathered surface. Possibly, previous denudations may likewise have destroyed portions of the Rootlet-bed in this locality, as they undoubtedly did on the Norfolk Coast, where, apparently, a large portion of the Rootlet-bed was denuded before the deposition of the Pebbly Sands, which underlie the Cromer Till or Lower Boulder Clay. Such may have been the case on this coast, north of Pakefield Lighthouse Gap, where a plane of denudation is shown between the Chillesford Beds and the overlying Pebbly Sands, the two coming together without the intervention of the unstratified Rootlet-bed, which last has been entirely eroded away, if it ever existed there. South of the Gap, at the spot where the *Unio*-beds occur, a portion of the Rootlet-bed is shown to have been eroded, previously to the deposition of the overlying beds, which have been classed with the Pebbly Series, on the published Section.

Many mammalian remains occur in places, scattered throughout the unstratified greenish-grey stiff homogeneous clay forming the Rootlet-bed. Some of the bones, however, are at times very difficult to extract without breaking; as they fall to pieces during the excavation of their clayey matrix.

“Many of the larger bones and fossils at Oxford have been mended with a whitish-coloured cement, which is exceedingly hard and tenacious.”* The cement mentioned is stated to be for large and ponderous specimens, and is thus made:—1 part bees’ wax, 4 parts resin, and 5 parts powdered plaster of Paris. Warm the edges of the specimens, and use the cement warm.

The following mammalian remains, which are now in the Museum of Practical Geology, London, I extracted from the Rootlet-bed with but few disasters. I had a misfortune, however, with the Rhinoceros upper tooth mentioned, which on being exhumed from its matrix, broke up into several fragments; and which took the whole evening to mend, the pieces forming quite a puzzle to put together.

A tooth and jaw of *Rhinoceros etruscus*, and many fragments of bones and antlers of a species of *Cervus* were found, and the precise position where each specimen† was obtained is marked on the published Section.

* Buckland’s Curiosities of Natural History, Ser. 2, p. 62.

† Identified by Mr. E. T. Newton.

Some black silt occurs in a slight basin-shaped hollow in the lower part of the Rootlet-bed 120 yards N. of the flagstaff at Kessingland (as shown on the engraved Section) where the following specimens* were obtained. Bone and teeth of a vole (*Arvicola intermedius*), scales of the perch (*Perca fluviatilis*), and a preoperculum of the pike (*Esox lucius*).

Besides the above, wood, seeds, fish-vertebræ and other bones, were obtained. A full list of the mammalian remains is given on pp. 89-91.

On the Coast at Corton.

I have seen the Rootlet-bed exposed along the shore, commencing at a point about 11 chains N. of Corton Gap, and continuing further northwards for about 67 chains, the exposure being thus a little more than three quarters of a mile in length, as is shown on the drawing of this Cliff-section.† It is only on very rare occasions, however, that so much of the bed can be seen at one time. The greater part of it is generally obscured by a covering of beach-sand, particularly during the summer months. The exposure referred to does not represent the total extent of the Rootlet-bed in this locality, but only so much of it as has been uncovered. This is on account of its lying at a very low level.

In character this bed, the top part of which is an old land-surface, is similar to that at Kessingland. It consists of a greenish and dark bluish-grey unstratified clay, with occasional white calcareous concretions ("race") and ferruginous sandy concretions, and it contains mammalian remains. It is overlain by peat varying from about 4 to 8 inches in thickness, containing flattened pieces of wood, matted reeds, etc., which for the most part are well preserved and seldom in the state of lignite. Amongst the fragments of wood noticed, one piece measured $30 \times 8 \times 1$ inches, another $18 \times 5 \times 1$. They were all apparently very much compressed.

Thousands of rootlets may be seen here, at times, penetrating the bed vertically, as they grew. They do not spread all over the area, but here and there, sometimes extending to a considerable distance. In places they are so thickly clustered together that the spaces between them in some instances measured less than an inch. This would tend to show that they do not, all at any rate, belong to large trees. They vary from about $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches in thickness at the surface and gradually taper away to nothing, as at Kessingland and Pakefield; all are more or less crumpled, similar in appearance, and only occasionally forked. There is no certainty, however, about their identification.

In the most northern part of the Rootlet-bed, as shown on the Section of this Cliff previously referred to, there are numerous fresh-water shells, chiefly univalves. They were observed for a distance of 120 yards, and from $1\frac{1}{2}$ to

* Identified by Mr. E. T. Newton.

† See Horizontal Section, Sheet 128.

4½ feet down from its surface, diffused throughout that portion of the bed. The following are the species identified:—

<i>Bythinia tentaculata</i> , and operculum.	<i>Planorbis spirorbis</i> .
<i>Helix</i> or <i>Zonites</i> (?).	<i>Succinea putris</i> .
<i>Limnæa stagnalis</i> , common.	<i>Valvata piscinalis</i> .
<i>Planorbis corneus</i> , common.	<i>Unio</i> or <i>Anodon</i> , (?) fragments.

Specimens of the following plants, besides others not yet identified, obtained from the peat immediately overlying the Rootlet-bed at Corton, have been identified by MR. REID, and are preserved in the Museum of Practical Geology, London:—*Ceratophyllum demersum*, Hornwort (seeds); *Potamogeton* sp., Pondweed (seeds); *Quercus* sp., Oak (wood); *Salix* sp., Willow (wood).

The elytra of Beetles have been observed; as, also, leaves of Oak and of Alder.

MR. JOSHUA TRIMMER referred to this Rootlet-bed in the following manner:—"I have seen patches of clay of a greenish-blue colour, and containing fresh-water shells and vegetable remains, at the base of the cliffs between Gorleston and Lowestoft."*

MR. S. R. PATTISON also referred to this Rootlet-bed and to the peat overlying it, and thus described the section he saw of it "on the beach under Corton"†:—

	Feet.
"An irregular bed of peat, surface and contents of marshes, compressed rush-like plants matted together, and much mineralized with sulphate of iron"	2
"An irregular surface below the bog, covered with roots and lower portions of stems of ferns (<i>Pteris</i> ?) <i>in situ</i> , in a dirt-bed; occasionally large trees"	5
"Dark clay, with a greenish tinge, underlying the heath-like deposit above, abounding in <i>Cyclas</i> , opercula of <i>Bythinia</i> ? and traces of other <i>Planorbis</i> -like shells, very small flint-pebbles and occasional peaty layers"	4

In the same communication, MR. PATTISON gives a descriptive section of the Drift-deposits that overlies this old land-surface; amounting to 80 feet in thickness. This amount is probably an exaggeration; or, at any rate, it was probably not seen in direct vertical sequence: and this may be inferred from the paper, as MR. PATTISON speaks of an *average* thickness of some of the beds. At the present time, their combined thickness does not amount to more than 58 feet on this part of the Coast, as depicted on the Cliff-section, previously referred to.

Horns, teeth or bones of the following mammalia have been obtained from the Rootlet-bed at Corton, those marked + being in the Museum of Practical Geology, London, the rest in Mr. J. J. Colman's Museum, at Corton, with other specimens not yet identified:—

- Cervus verticornis* + (base of antler).
- sp. (teeth and parts of antlers and bones).
- Cetacea*, +
- Elephas antiquus* (4 fine teeth belonging to one animal).
- *meridionalis* (tooth).
- sp. (bone).
- Hyæna crocuta*, var. *spelea* (4 teeth).
- Rhinoceros etruscus* (teeth, etc.).

The occurrence of the Cave Hyæna (*Hyæna crocuta*) in the Rootlet-bed of the Norfolk and Suffolk Coast, was recorded for the first time by MR. E. T.

* *Journ. Roy. Agric. Soc.*, vol. vii., p. 444. (1847.)

† *Geologist*, vol. vi., p. 207. (1863.)

NEWTON in 1883.* The four teeth figured and described by him are those mentioned in the above list, which were found whilst some excavations were being made by Mr. J. J. Colman, M.P., at the base of the cliff S. of Corton Gap and beneath the level of the beach.

The fine Elephant teeth mentioned in the above list were considered by DR. LEITH ADAMS to be a "broad variety" of *Elephas antiquus*.† They are the last upper and lower molars of both sides of the jaws belonging to one individual. DR. ADAMS says that the lower molar "as regards length, is the largest molar of any Elephant I have seen from British Strata." He also remarks that this is larger than *E. meridionalis*. Whilst on the coast one day, I had the good fortune to meet the man who discovered these specimens. He pointed out to me, as near as he could, the spot where they were obtained, which spot has been marked on the Section of the cliff. It was near low-water mark about 42 chains N. of Corton Gap, or about 120 yards N. of where the Boulder Clay at the top of the cliff terminates. The teeth were embedded in the jaws, which were, most unfortunately, hacked to pieces during the process of extraction. The man had only time to get out one tooth on the evening he discovered the jaws, inasmuch as the sea came up. Early next morning the bed was again uncovered, and the jaws, on account of their being so firmly embedded in their clayey matrix, were found in the same position, not having been washed away. Another man, however, who had been an onlooker during the previous evening, arrived first on the scene, and successfully extracted the other three teeth before the original discoverer turned up.

Age of the Rootlet-bed [Forest-bed].

In a paper published in 1877,‡ I alluded to the age of this Rootlet-bed with respect to the Drift deposits that overlie it. This was done because MESSRS. WOOD and HARMER had suggested, in Papers read before the Geological Society, that the Rootlet-bed at Kessingland was newer than the Contorted Drift or Lower Boulder Clay. Attention, therefore, was drawn to the fact that the continuation of this bed was to be seen at the base of Corton Cliff, where it underlaid both the Pebbly Sand and the Lower Boulder Clay (Lower Glacial of WOOD and HARMER); and also that it occupied a similar position at Happisburgh and Runton, and the following statement was made:—"I . . . have not the slightest doubt as to the identity of this remarkable bed . . . which is exposed at intervals at the base of the Norfolk and Suffolk Cliffs, from Kessingland to Runton," a distance of about 47 miles. Since then it has been traced by MR. C. REID, as anticipated, about 4 miles further, to Weybourn, where the cliff-section ends, and where the bed occupies a similar position as at Corton and Happisburgh.

In the paper referred to, the Rootlet-bed was described as marking "an horizon of considerable importance with respect to the correlation of the beds in Norfolk and Suffolk," and as occurring "at the upper part, or thereabouts, of what is generally known as the Cromer Pre-glacial Forest-bed series, and beneath the Lower Glacial series of Messrs. Wood and Harmer."

The relation of this bed to the Chillesford Clay was treated of in my Address to the Norwich Geological Society in 1880. Then,

* *Geol. Mag.*, dec. ii., vol. xi., p. 433.

† These teeth are described very fully in his Monograph, *Pal. Soc.* 1881, p. 174.

‡ *Geol. Mag.*, dec. ii., vol. iv., p. 298.

after stating that the true stratigraphical position of the Rootlet-bed (frequently called a Forest-bed) was of considerable geological interest, it was said "All the evidence, as shown by superposition, etc., in my opinion clearly points to the conclusion, that it immediately overlies the Chillesford clay. The Rootlet-bed in some cases apparently being a freshwater deposit, as at Corton and at Kessingland; sometimes forming a distinct and separate bed one stage more recent than the Chillesford clay, and sometimes apparently passing down into the Chillesford clay, forming, as it were, the uppermost portion of the same; at other times it is to be seen lying on a more or less denuded surface of the Chillesford clay, as at Weybourne."*

IN treating of the Chillesford Beds, it was remarked that the laminated clays that underlie the Rootlet-bed at the extreme end of Kessingland Cliff precisely resembled those to be seen at the northern end of Covehithe Cliff, $2\frac{1}{2}$ miles further south. Referring to this fact in my Address it was stated that "after going backwards and forwards from one cliff to the other, on several different occasions, I could not resist the conclusion that it was the extension of the same formation, designated the Chillesford beds." (p. 149.) That such is the case seems to be demonstrated by the geological mapping of the ground in the neighbourhood of Kessingland. My colleague, MR. WHITAKER, has traced the laminated clays from Easton Bavent and Covehithe northwards to their outcrop along the southern border of the alluvium or marsh-land, through which the stream meanders that finds its outlet at Benacre Sluice†; whilst I have traced the laminated clays from Kessingland Cliff westwards to where they outcrop along the northern border of the said alluvium, until, in the upper part, the latter so narrows that the laminated clays on either side are within a few yards of one another, and on the same level; thus clearly showing, beyond any reasonable doubt, that they are on the same horizon, and a continuation of the same formation. Moreover, there are no other laminated clays in the district with which they can possibly be mistaken.

This being so, and as these laminated clays (Chillesford Beds) are shown at Kessingland Cliff to underlie the Rootlet-bed, the stratigraphical position of the latter is thus proved by direct superposition.

FRESHWATER BEDS. (By C. REID.)

Overlying the Rootlet-bed there occasionally occur thin deposits of freshwater loam or peat. The thin peat-beds at Kessingland and Corton have already been alluded to; but the thicker deposit at Pakefield deserves a fuller description. This was originally classed with the Pebbly Series (above), in the

* *Proc. Norwich Geol. Soc.*, part v., p. 152.

† See Memoir on the Geology of Southwold, 1887.

published Section and Explanation ; but later observations (made since MR. BLAKE finished the survey of the district) have tended to show a closer connection with the Forest-bed Series (below), especially in the character of the fossil plants, recently collected. MR. BLAKE still prefers to class these peaty beds with the overlying Pebbly Series. The following description has been taken from his Explanation of the Section.

This patch "occurs south of Pakefield Light-house Gap, preserved in the very shallow basin-shaped hollow, cut partly out of the Rootlet-bed to the south and partly out of the Chillesford-beds to the north. This deposit (previously referred to in the description given of the Rootlet-bed in connexion with the *Unio*-bed) consists of finely stratified and laminated brown and grey loamy clay, stained black in places with carbonaceous matter ; nearly the whole thickness sometimes being so stained for more than 100 yards in length. In consequence of this staining the deposit has sometimes been described and referred to as the "Black-bed." Pieces of wood and other vegetable matter occur in these laminated beds, particularly in the lower part ; and a flattened trunk of an oak was observed resting on the curved slope at the southern end, as shown on the Section." Stools of trees have also been observed here.

[The plants noted on p. 92 were from this hollow. See C. REID, *Trans. Norfolk Nat. Soc.*, vol. iv., p. 194, (1886).—W. W.]

CHAPTER IV. PEBBLY SERIES.

GENERAL REMARKS.

This deposit, which varies much in lithological character in different localities, was first brought to the notice of geologists by MR. S. V. WOOD, jun., who in 1866 applied the term "Bure Valley Beds" to it, on account of the greatest exposure and the principal fossiliferous localities, in his opinion, occurring in the valleys of the Bure and of its tributaries. He showed by diagram and sections the range of the Series from the Bure Valley, past Norwich, to the neighbourhood of Southwold, as well as its inferiority to the so-called Contorted Drift, and its superiority to the Chillesford Clay.* These beds, however, in the Bure Valley have been grouped with the Norwich Crag by MR. H. B. WOODWARD. It is quite true, according to my own investigations, that there is such a deposit, and that it occupies a definite horizon, and such as that described by MR. WOOD.

But mistakes have been made in correlation: beds on the horizon of the Norwich Crag, *beneath* the Chillesford Beds, have been correlated with those on the horizon of the Pebbly Series *above* the Chillesford Beds.

On the maps the Pebbly Series has been left unbracketted either with the Crag below or with the Drift above. (*See Southwold Memoir.*)

In this district the Pebbly Sand is exposed at the base of Corton Cliff, where it occurs between the Lower Glacial Loam and the Rootlet-bed, excepting where, owing to disturbance, as shown, the Lower Boulder Clay rests directly upon the Rootlet-bed for a short distance.

ON THE COAST AT KESSINGLAND AND PAKEFIELD.

Some laminated clays, probably of the age of this Pebbly Sand, occur in places at the base of Kessingland and Pakefield Cliff, as shown on the Section, in the Explanation of which they have been thus described:—"The first indication of this deposit shown on the Section occurs near the lenticular bed of grey marly clay—containing ripple-marks—in the "Middle Glacial" sands. It consists of more or less laminated and contorted grey clay, obliquely bedded ferruginous gravel intermixed with numerous patches of grey clay, and brown and orange-coloured pebbly sand,—indurated in places. It partly rests on the grey clay of the Rootlet-bed, and partly on the black peat covering this."

"The other portion referred to the age of this deposit occurs mostly north of Pakefield Lighthouse Gap, where it overlies the Chillesford Beds without the intervention of the Rootlet-bed; which last, if ever present there, has been denuded previously to

* See Supplement to the Crag Mollusca, p. 15, footnote.

the deposition of the Pebbly Sands. There are clear indications of a line of denudation on the top of the Chillesford Beds here, as there are likewise on the top of the Pebbly Sands; but to a greater extent apparently on the top of the latter than the former. These Pebbly Sands are mostly white and brown in colour, but rust-stained and more or less indurated in the upper part beneath the line of denudation; and they contain numerous pellets of micaceous grey clay, evidently worked-up portions of the underlying Chillesford Clay."

ON THE COAST AT CORTON.

In the Explanation to the Cliff-section, this formation has been thus described:—"This variable deposit occurs, as shown on the Section, between the stony loam or Lower Boulder Clay and the black peat-covered surface of the Rootlet-bed. It consists of buff and ash-coloured pebbly sands containing patches of clay and ferruginous concretions, laminated or well-stratified grey and brown clay, and ferruginous gravel and sand ("pan"), particularly at its base, where also a little ochreous-coloured clay occasionally occurs overlying the black peat. No fossils have been observed in any portion of this deposit at Corton." In about five or six different places some oblique-bedded buff sand and gravel, with seams of grey clay, were seen, and here and there a little oblique-bedded reddish-brown indurated sand. A few other kinds of current-bedding occur, in the form of small basin-shaped hollows or erosions, containing bedded sand in concentric curves. Many very irregular-shaped patches of grey and brown clay are likewise to be seen in these sands, the latter in places being coarse, and containing pebbles of quartz and of flint, which are abundant in the southern portion of this deposit.

LOCAL DETAILS.

Burgh (Castle).—About five eighths of a mile S. of the church, buff sands crop out from beneath the stony Loam (Lower Glacial). They were well exposed along the escarpment close to the Waveney, and about 66 yards north of the road were 15 feet thick, though not bottomed. In the brickyard about 130 yards north of the road, a section showed 7 feet of stratified and false-bedded buff sand, underlying from 9 to 12 feet of stony Loam. The base of the latter rose towards the south, until it reached the surface of the ground at the point mentioned above, where sand, 15 feet in thickness, underlaid it. The sand was very fine, and very free from pebbles; whereas that of Glacial age, overlying the stony Loam, was unusually pebbly.

In the brickyard further north, near the Cement Works, buff sand was exposed underlying Lower Glacial loam, 15 feet thick.

The relation of the various deposits here is shown on Fig. 3 (p. 55). The detailed description of the beds above the Pebbly Series being given on pp. 32, 42, 54-56.

Gorleston.—Some laminated beds, consisting of alternations of clay and sand, have been observed, on a few occasions, on the fore-shore at low-water spring-tides near Gorleston Breakwater, and continue here and there to a distance of nearly a mile southwards. They were very similar to some laminated beds that intervene between the Rootlet-bed and the stony Loam

(Lower Glacial) in the lower part of the cliff at Corton, and are probably of the same age.

Somerleyton.—In a pit a little N.W. of the railway-station, and adjoining the brickyard, a thickness of 21 feet of gravel and sand was exposed. The upper 15 feet, consisted of well-rounded flint stones and pebbles, resembling shingle, intermixed with sand; the gravel and sand being in about equal proportion, and occasionally false-bedded. The section, however, was shown to vary laterally, there being less shingle in some parts than in others; and patches of grey loam were present in places. The lowest 6 feet exposed, consisted of stratified white and buff sand, with a little of an orange-tint, very micaceous, slightly loamy in places, and very similar to some portions of the Chillesford Beds in other parts. This sand seemed to be unconformable to the overlying shingle and sand, and, so possibly, may be of Chillesford age.

These beds seem to have been found in wells at Somerleyton (see p. 83), and the well-sinker who gave the information stated that the gravel in the land near the marshes contains iron-pan; but that the sand in the neighbourhood of the village is very free from it.

Herringfleet.—Two small sand-pits about a quarter of a mile S. of the church, on the western side of the road, and close to the marsh-land, showed numerous thin bands of grey loam interstratified with buff and white sands, micaceous in parts. Pellets of clay and loam also occurred in places, some having a ferruginous coating. In one of the pits, the sand had much oblique bedding in the lower part, and gravel, more or less of a chocolate-colour, occurred intermixed with the sand in the upper part.

Blundeston.—The well at Warren Farm is in this Series (see p. 83).

Burgh St. Peter.—In a pit a little more than three quarters of a mile W.N.W. of the church, about midway between Stockton Farm and Orford's Farm, the section was as follows:—

	FET.
Gravel, pebbly, apparently unconformable to the underlying sand	3
Sand, light-yellow and white, loamy and micaceous, varying in places	10
Gravel, coarse, reddish-brown or orange-coloured, similar to shingle	5

Another section is described further on, p. 46.

Wheatacre.—A gravel-pit three quarters of a mile N. of the church, a little N. of Mouser Farm, showed 12 feet of reddish-brown gravel, over buff pebbly sand.

Ellough.—About five eighths of a mile W.S.W. of Hulver Bridge, a small gravel-pit, close to the marshes and on the southern side of the road, showed 6 feet of pebbly and subangular gravel, more or less indurated, overlying slightly indurated light-brown sand. The gravel consisted mostly of flints intermixed with pebbles of quartz and quartzite. The stones were mostly from 1 to 4 inches in diameter, but some subangular flints measured as much as 6 or 7 inches.

Kessingland.—A small pit occurs five eighths of a mile S.W. by S. of the church. In one part from 2 to 3 feet in thickness of coarse gravel was exposed, ferruginous and stained black in places, both subangular and pebbly, and mostly consisting of flint with a few quartz pebbles intermixed. In another part, about 20 yards from the gravel, 5 feet in thickness of sand was exposed, with a band of laminated grey clay and sand in it, the upper part being more or less indurated and with ferruginous stains. This band was 3 feet beneath the surface of the ground, the sand above it being buff and that below orange-coloured, well-stratified, and with ferruginous streaks. The gravel was apparently on the same level, but the connection was not shown, owing to talus, &c. obscuring the section.

Mutford.—The section here is described above, p. 15.

CHAPTER V. GLACIAL DRIFT.

GENERAL REMARKS.

With the exception of the Alluvium of the marsh-land, which occupies a large tract of country, the shore-deposits, and the small patches of Pliocene beds previously described, the whole of the area to which this Memoir refers consists of Drift.

The nomenclature adopted (*see* p. 5) includes terms which have been in very general use by the best authorities for many years, especially since MESSRS. S. V. WOOD, jun., and F. W. HARMER published their "Outline of the Geology of the Upper Tertiaries of East Anglia." *.

The existence in this district of an Upper and a Lower Boulder Clay, with a great mass of sand interposed, was first brought prominently into notice (through MR. JOHN GUNN drawing attention to the fact) by MR. JOSHUA TRIMMER, in 1858.† He says: "On visiting the Cliffs with Mr. Gunn, I found their structure to be as he had described it," that is, "two boulder-clays separated by a mass of sand."

In 1865 MR. S. V. WOOD, jun., used the terms Upper Drift, Middle Drift, and Lower Drift. These in 1872 he, in conjunction with MR. HARMER in their "Outline, etc.," previously referred to, converted into Upper Glacial, Middle Glacial, and Lower Glacial; and coupled with the last the Pebbly Sand (in part the Bure Valley Beds) which underlies the Lower Boulder Clay.

LOAM, WITH BOULDERS. [LOWER GLACIAL.]

General Remarks.

This division consists of unstratified homogeneous brown stony loam, occasionally mottled with red, and frequently with grey in its lower part. Numerous fragments of marine shells occur in places interspersed throughout its mass; and here and there well-striated boulders of igneous, metamorphic, palæozoic and other rocks, some of which are considered to be of Scandinavian origin. Whilst the base of the formation exhibits a remarkably fine and sharp line, similarly to the base of the Upper Boulder Clay, its surface or uppermost portion generally presents an irregular or eroded appearance. It is in part probably of the age of the "Cromer Till" of the Norfolk Coast, and in part of that of the overlying so-called "Contorted Drift." These deposits (which were named by MR. S. V. WOOD, jun.) in places become so merged one into the other, as shown in the Cliffs between Bacton and Weybourn, that frequently they cannot be separated.

* *Preface to "Supplement to the Crag Mollusca," Palæontograph Soc., 1872.*

† *Quart. Journ. Geol. Soc., vol. xiv., pp. 171-174.*

MESSRS. WOOD and HARMER, in their "Outline, etc.,"* previously referred to, have described the Lower Glacial Loam that occurs in this district under the term "Contorted Drift." This is somewhat misleading, inasmuch as the deposits that they include generally under this term are those that intervene between the top of the Cromer Till and the base of their Middle Glacial sands; whereas I regard the greater part of this loam as being on the same horizon as the Cromer Till, as does also Mr. J. GUNN. This Cromer Till, which at Happisburgh is blackish or dark bluish-grey, when traced to Walcot, is shown to change gradually to brown [by weathering], where not overlaid, as at Happisburgh, by stratified clays and a chalky till, which latter has been mistaken for the Upper Boulder Clay by some observers. The Cromer Till at Walcot, Bacton, and elsewhere, is precisely similar in appearance to the Lower Glacial Loam in this district, at the base of the cliff at Corton.

In our district there is no passage upwards from this division into the Glacial Sand. Here, and probably for a considerable distance further south, an unconformity exists; for large portions, and in places the whole mass, of the Lower Glacial Loam has been denuded prior to, or during, the accumulation of the Glacial Sands as is clearly exhibited in the cliff at Corton.

This loam occupies a large area north of Yarmouth, but only a comparatively small area to the south, principally in the neighbourhood of Blundeston, Somerleyton, and a few other places. In both areas, however, there are sections showing a maximum thickness of about 21 feet.

On the Coast at Corton.

This deposit can be traced in the lower part of the cliff almost continuously, from south of Corton Gap nearly to League Hole, a distance of a little more than $1\frac{1}{4}$ miles. It here consists of an unstratified brown stony loam, occasionally mottled with grey, with numerous fragments of marine shells in places, interspersed throughout; and very sparsely scattered boulders of igneous, metamorphic, palæozoic and other rocks. It varies much in thickness, but is nowhere, along this coast, more than about 12 feet thick. Joints, more or less ferruginous, occur in it just north of Corton Gap, in a similar manner as in the loam of the same age at a brickyard near Wash Lane Farm, about $1\frac{1}{4}$ miles S. of Beccles Church. It is quite clear, as will be seen from the Section,† that there was a considerable amount of denudation of this stony loam in this neighbourhood, before, and probably during, the deposition of the Glacial Sand; so much so, that in some places the whole thickness of this no doubt once continuous bed of loam has been eroded, and in others very nearly so, mere remnants being left. The Glacial Sands, consequently, occasionally

* Supplement to the Crag Mollusca, p. xx.

† Horizontal Sections, Sheet 128.

lie immediately on the Pebbly Sand, and were it not for a very marked ferruginous line in the cliff which shows the junction of these two very similarly coloured sands of different ages, they might be mistaken locally, for deposits belonging to the same formation.

Amongst the occasional or sparsely scattered boulders that are to be found in this loam, those of basalt are rather common, and frequently they have their columnar structure well preserved.

On the Coast at Kessingland and Pakefield.

There is nothing that can with certainty be referred to the age of this loam in the cliffs at Kessingland and Pakefield. Possibly, the very compact unstratified reddish-brown, and in places chocolate-coloured, sandy loam, mentioned on the drawing of this Cliff-section as occurring in the basin-shaped hollows on either side of Pakefield Lighthouse Gap, may be of this age. The evidence seems to show that these shallow basin- or rather saucer-shaped hollows were cut out after the deposition of the Pebbly Sands and filled in before the deposition of the Glacial Sands. At the same time, it must be admitted that the lithological character of the deposit is dissimilar to that of the wide-spread mass of stony loam or brick-earth, that occurs in the neighbourhood of Corton, Blundeston, Somerleyton, Norwich, and other localities, and is sometimes described under the term "Contorted Drift."

Local Details, North of Yarmouth.

Waxham.—The excavation in a brickyard close to Waxham Hall, a little S.W. of the church, showed 12 feet of brown loam, stony in places, and bluish in the lower part; brown sand underlaid this, and water came in as soon as it was reached.

The loam was also found in a well here (see p. 81).

In a low cliff E.N.E. of Waxham Church, in front of the natural embankment of Blown Sand, the section showed at least 6 feet of brown stony loam.

West Somerton.—Immediately north-west of the church, a large pit from which much material has been excavated for the manufacture of bricks, gave the following section:—

Boulder Clay, 5 or 6 feet.

Buff sand; thickness not determinable, from the pit being much overgrown, but probably 10 to 15 feet or more.

Reddish-brown unstratified loam; stony in places, with oval and lenticular patches of buff sand, in which (as well as scattered throughout the loam) were many fragments of marine shells. The following were observed by Mr. Whitaker and myself:—*Cardium*, *Cyprina*, *Mya*, *Pholas*, and *Littorina rudis*. ? to 15 feet.

Martham.—At a brickyard, a little more than a quarter of a mile N.N.E. of the church, on the eastern side of the road, 10 feet of brown loam was exposed, underlying 9 feet of well stratified buff Glacial Sand; with a little ferruginous gravel, 4 inches thick in places, intercalated between the sand and the loam. Small oval patches of buff sand occurred in the loam, which latter here dips towards the north.

At another brickyard a little south of the above, on the western side of the road, the loam is likewise shown dipping towards the north, the section being:—

Reddish-brown loam, the tailing off of the Boulder Clay; 3 or 4 feet.
Glacial sand; 3 or 4 feet.
Loam; 15 feet.

At an old pit close to Martham Church, on the western side of the road, the loam is several feet in thickness and somewhat sandy.

A pit occurs five eighths of a mile S.W. of Martham Church on the northern side of the road, where 7 feet in thickness of brown loam was exposed. Boulders occur sparsely scattered in it: amongst them was one of basalt, in a more or less decomposed condition, similar to many seen in the brown stony loam at the base of Corton Cliff.

The section at a brickyard on the southern side of the road, five eighths of a mile S.W. of Martham Church, was as follows:—

		FEET.
Glacial Drift	Sand and Gravel	Buff sand, stratified and false-bedded in places, and containing some impersistent bands of more or less indurated brown sand - - - 14
		Ferruginous gravel and sand - - - 1 to 2
	Loam	Brown loam and loamy clay - - - 8
		Cream-coloured loam (described as being like fullers' earth) the bottom of which was not reached when a hole was dug to ascertain its depth - - - 16+

To the west of the railway-cutting, between the railway-station and Martham Hall, dark brown loamy clay was exposed in trial-holes, sunk to a depth of 3 feet.

In a fresh-cut ditch (April 1878) by the side of the railway S. of Martham Hall, 5 feet of reddish-brown loamy clay, more or less mottled with grey, was exposed.

Hemesby.—In the railway-cutting north of the church, when the excavation was in progress, sections were exposed showing mottled red and grey Loam, much contorted. In one place at the southern end, the Boulder Clay was shown to lie immediately on the loam; but there was a considerable thickness of buff sand mixed up with the loam, the beds beneath the Boulder Clay presenting a much-disturbed or contorted appearance. At the northern end of the cutting, there was no displacement or irregularity in the beds; the Boulder Clay (very loamy in places), and 6 feet thick, was shown to overlie a considerable thickness (10 to 15 feet or more) of buff sand, and the latter to overlie reddish-brown stony loam, the succession of these three Glacial deposits being very clearly shown in section.

At the brikiyard, three eighths of a mile S.S.W. of Hemesby Church, an excavation showed unstratified brown loam, varying from 9 to 12 feet in thickness. It was very free from stones, and of sufficiently good quality to make bricks without the admixture of other ingredients.

In the road-cutting, S.E. by S. of the church, where the diversion of the road has been made on account of the railway, a considerable thickness of mottled red and brown loamy clay was exposed, containing irregular-shaped patches of buff sand.

Similar mottled loamy clay was exposed in the railway-cutting N.E. of Hemesby Church, about 2 chains north of the road.

Ormesby St. Margaret's.—At a small brickyard in Scratby Field, three quarters of a mile E. by N. of the church, I was informed there was 14 feet of brown loam (mottled with a little grey) overlying 5 feet of sand, which latter rested on loam that had been dug to a depth of 5 feet. The loam exposed was somewhat sandy, and contained irregular patches and seams of light brown sand.

Brown loam, 20 feet or more in thickness in places, and greyish-brown in the lower part, is exposed in a road-cutting leading to the beach at California, near Scratby. Fragments of marine shells, *Cardium*, &c. were observed in the greyish-brown part. The beds below the loam in the cliff are hidden by blown sand.

In the middle of a field, a little more than a quarter of a mile E. of Ormesby St. Margaret's Church, an excavation occurs where loam has been dug for the manufacture of bricks. The section exposed showed stiff brown loam, 12 feet or more in thickness, resting on sand. A little north of this spot was another excavation where Glacial Sand had been dug to a depth of 6 feet; but the total thickness of sand here, between the Boulder Clay and the loam, is probably 12 to 15 feet or more. Some patches of Boulder Clay, about 2 feet in thickness, were exposed on the slope of the hill.

The following section was exposed at a brickyard about half a mile E. of Ormesby St. Margaret's Church, on the southern side of the road:—

	FEET.
Glacial { Buff sand, with a little gravel at the base, lying	
Drift { irregularly on the next - - - - -	3
Drift { Brown loam, somewhat sandy, containing a very few	
stones - - - - -	14
Pebbly sand, containing bands of clay - - - - -	5

In the "Gap" at California on the coast is a section of loam mostly reddish-brown, about 18 feet in thickness, and apparently free from stones, except in the upper part. The section is much obscured by blown sand, and overgrown with marram grass.

Thrigby.—In a small pit in a field a quarter of a mile N.E. of the church, loam was dug for the manufacture of bricks in 1878.

Runham.—The following section was exposed in a small brickyard nearly a mile N.E. of the church, on the western side of the road leading to Filby church:—

	FEET.
Glacial { Brown loam, with a very few scattered small	
Drift { stones - - - - -	8
Drift { Light brown sand (probably a lenticular patch in	
the loam) - - - - -	3
Drift { Brown loam, rather stiffer than that above - - - - -	5
Pebbly Series. Ferruginous gravel ("pan"), thickness	
unknown.	

Local Details, South of Yarmouth and around Lowestoft.

Burgh (Castle).—This Loam here resembles in irregularity of thickness and in other particulars that in the cliff at Corton (*see* p. 29). Good sections were seen at the brickyards south of Burgh Castle, near the Cement Works. The loam varied from 9 to 15 feet in thickness; but, in one place, where the section was hidden with talus, it was stated to be only 5 feet thick; and in another, only 2 feet. It was unstratified; reddish-brown, but mottled and streaked with grey in places, and occasionally somewhat chalky. Small flints and quartz pebbles occurred interspersed throughout, some places being free from them as compared with others. Occasionally there were subangular flints up to 6 inches in length; and a boulder of quartz, measuring 4 inches, was seen. There were also, in places, a few patches of buff sand in the loam; and, here and there, some fragments of marine shells. In the brickyard furthest to the south, a section showed 9 feet of loam at one end, and 12 feet at the other; between which four wedge-shaped masses of loam, emanating from that beneath, penetrated into the overlying Glacial sands. (*See* Fig. 3, p. 55.)

Gorleston.—Stony loam, similar to that in the lower part of the cliff at Corton, was seen in a few places on the shore between League Hole and

Gorleston Breakwater, when the beach, which usually overlies it, had been scoured out by the sea. On one or two occasions, a patch of this stony loam 3 feet in thickness was observed underlying the Glacial sands at the foot of the cliff, a short distance south of the Breakwater, and close to a post with a board on it, containing a notice concerning bathing-regulations.

Blundeston.—At the brickyard a quarter of a mile N.E. of the church, immediately north of the wind-mill, 15 feet of unstratified brown stony loam, with small flints and quartz pebbles diffused throughout, was exposed, overlying buff and white sand, 2 feet only of the latter being shown.

In another pit, about 12 chains N. of the church, 9 feet in thickness of similar loam was exposed, without reaching the bottom.

Somerleyton.—At a large brickyard close to the railway-station, the following section was exposed in an excavation on the western side, adjoining the road :—

	FEET.
Plateau Gravel, &c. Sand and Gravel, more or less piped into the underlying clay	4 to 6
Boulder Clay	5 to 14
Glacial Drift { Patch of buff sand, at one place.	
{ Brown stony loam unstratified, containing sub-angular flints, and quartz and flint pebbles	18 to 20
Pebbly Series { Pebbly sands, yellow and orange-coloured	3
{ Grey clay underlain by black clay, both more or less laminated	3
{ Sand, light-brown and white, indurated in places, and containing a little grey clay at top	5

Oulton.—In an old pit about half a mile W. of Gunton Church, and a quarter of a mile E. of Park Hill Farm, on the western side of the road and the southern side of the valley, the following section was exposed :—

Boulder Clay; 4 feet.

Loam, brown, more or less stratified, and free from stones; sandy in some places, clayey in others; with a lenticular patch of buff sand in the upper part; 9 feet.

In the north-eastern corner of an old brickyard adjoining Park Hill Farm the following section was seen :—

Sand, buff and brown (Middle Glacial); 3 feet.

Loam, unstratified, reddish-brown, free from stones; with a lenticular patch of stratified whitish-grey clay and brown sand, 10 feet long and 1½ deep at most, in the middle; 12 feet.

In another and much larger pit, at Brick-kiln Farm, on the northern side of the valley, five eighths of a mile N.W. by W. of Gunton Church, and adjoining the road, a very fine section, about 80 yards in length, and for the most part clean-cut, was exposed, as follows :—

Grey Boulder Clay; 6–8 feet.

Brown Loam; 21+ feet.

The junction was very marked, and showed an undulating line with no admixture of the two dissimilar formations. On the western side, furthest from the road, the section showed 20 feet of loam, the upper 10 feet unstratified; but the lower part containing a few thin grey seams and a little buff sand in undulating planes, thus presenting a slightly stratified appearance. At about 16 or 17 feet down from the top of the loam, a patch of dark grey loamy clay, 1 foot 6 inches thick, occurred, underlain by a little sand and brown loam containing shells. In the middle part of the section the loam had been excavated to a depth of 21 feet and not bottomed. It was reddish-brown; unstratified, mottled with grey in places, and stiffer and stronger

towards the bottom, where also it became more grey. Here, there were two large patches of buff sand in the loam, containing a little fine gravel and carbonaceous matter in places, and numerous fragments of shells, together with several that were whole, but in too fragile a condition to extract without breaking, the only ones that could be identified being *Tellina balthica*, *T. lata*, of both of which there were many whole shells, and fragments of *Cardium edule*.

Some of the lower part of this loam was much contorted, together with some of the shelly sand. On the eastern side, adjoining the road, the loam had been excavated to a depth of 20 feet and again not bottomed. It was unstratified and very similar to that described, and contained two patches of light-buff sand, from 2 to 4 feet in thickness. The whole of the Loam in this brickyard was very free from stones.

North Cove.—In one part of an excavation made at a brickyard near Low Common, about half a mile N. of the church, from 2 to 3 feet of Boulder Clay was shown resting on reddish-brown loam, more or less mottled with grey, which had been excavated to a depth of 8 feet, but not bottomed.

Mautby.—I was informed that the fields near Mautby Hall were clayed about the years 1866 to 1870, with chalky clay obtained from a spot about half a mile E. of Decoy Farm, where it was found beneath brown loam. There are two pits there, now filled with water, but in places the clay was seen beneath the loam.

West Caister.—There used to be a brickyard adjoining the marshes, about five eighths of a mile S. of Caister Hall, where loam was excavated.

East Caister.—Loam was excavated, and bricks made from it, in a field about a quarter of a mile N. of the church, and eastward of the road.

CHAPTER VI. GLACIAL DRIFT (*continued*).

SAND [MIDDLE GLACIAL OF WOOD].

General Remarks.

This formation mostly consists of well-stratified buff sand, containing in places numerous fragments of marine shells, chalk-grains, and occasional gravelly patches, and showing much false-bedding. In different localities it is shown to vary from about 30 to 50 feet or more in thickness, as on the coast at Kessingland, Pakefield, and Corton. In some other places, however, it may be as much as 70 feet.

It is clearly intercalated between the Upper Boulder Clay and the Lower Boulder Clay (or loam), hence the term "Middle Glacial" given by MR. S. V. WOOD. It is shown to occupy this position between the two Boulder Clays in the cliff at Corton,* where the three deposits occur in direct superposition, as they also do in some inland pit-sections.

The geological mapping of the ground, moreover, clearly proves it to occupy this definite horizon over an extensive area in East Anglia. In the area to the south, this sand occupies a large extent of ground, and is shown to be intercalated between the Upper and Lower Boulder Clays in many places. But, owing mostly to the low level at which the Lower Boulder Clay lies, together with the large amount of denudation it has undergone, the Geological Survey Map of the district around Lowestoft does not show the sequence of the three deposits in nearly so marked a manner as does the Map of the district N. of Yarmouth.

Occasionally, owing probably to disturbance, the Upper Boulder Clay rests directly upon the Lower Boulder Clay, without the intervention of the Glacial Sands, as at Somerleyton brickyard, and in places near Gunton; in the same manner as the Lower Boulder Clay occasionally rests for a short distance upon the Rootlet-bed, without the intervention of the Pebbly Sand, as at Corton cliff.

Here and there, in many localities in this district and elsewhere, small portions of the sand are indurated into irregular-shaped masses of hard rock. These occur amongst the loose sand, mostly in the upper part of the formation near its junction with the Boulder Clay, and are evidently due to calcareous infiltration. There is also, sometimes, much ferruginous matter at the junction of the clay and sand, occurring in places in the form of a band of iron-oxide about an eighth of an inch or more in thickness.

There may be some difference of opinion as to the appropriateness of the term Middle Glacial to these marine sands.

* See Horizontal Section, Sheet 128.

But as it has been largely used in geological literature with reference to the Molluscan remains, &c., it has been referred to in this Memoir. It is obvious, however, that the term "Glacial" has no reference whatever to the method of formation of this deposit, but merely to its geological period.

Much interest is attached to these sands, on account of the profusion of Molluscan remains in them, in this district. These occur, however, almost entirely in a fragmentary and comminuted condition, whole shells being very rare. They are moreover, very much water-worn. There is some difference of opinion as to whether they are of the age of the formation, as MESSRS. WOOD and HARMER* thought, or were derived from pre-existing Crag-beds, a view in favour of which some other geologists have expressed their opinion.†

"These remains," says Mr. S. V. WOOD, jun., "present much the same aspect as those from the newer part of the Red Crag; but there are some of which no trace has been found in the Crag, such as *Tellina Balthica*‡ and *Venus fluctuosa*, both of which occur in the Bridlington bed [Yorkshire], and another, unknown elsewhere, to which my father gave the name of *Trophon mediglacialis*, all of which are not uncommon in this band. There are others, such as *Venus fasciata* (which is unique in the Crag), that occur in this band in great profusion; and this is one of the two species found in Sheet 47, the other being *Astarte compressa*, also occurring in Sheet 67 in great profusion and in a more perfect state than any other species than floaters, but which is also common in the fluvio-marine Crag [Norwich Crag] and in the sand b 1 [Bure Valley Beds]. There are also other very small and tender species not known from the Red Crag, but which are Coralline-Crag shells, and have occurred in the Chillesford bed and fluvio-marine Crag, and whose absence from the Red may be attributed to the unfavourable conditions of that formation for their preservation. In the 'Introduction' above mentioned [to the Supplement to the 'Crag Mollusca'] Mr. Harmer and I gave our reasons, based on the character of the species themselves, for regarding these remains in Sheet 67 as not having been derived from the destruction of beds of Red or fluvio-marine Crag age, or from the Chillesford bed; but at the same time we pointed out that the remains had an origin which was distant from the place of their occurrence, and had, most of them, been greatly worn during their transport to it by currents along the bottom, the larger shells being for the most part fragmentary, but the smaller species and fry of the larger being often preserved entire, though worn, while with these were an abundance of the valves of *Balanus*, quite unworn, and of the papyraceous valves of *Anomia ephippium* in a perfect state, but which the least wear would destroy ['all young shells from $\frac{1}{8}$ th to $\frac{1}{4}$ of an inch in diameter,' Supplement to Crag Mollusca, p. 23]. The presence of these we attributed to their having been adherent to floating bodies, such as seaweed, and carried, thus adherent, floating in the currents which moved the sand with the shells and shell-fragments over the bottom, to subside as they became detached, all of which I still believe to be correct inferences."

He then gives the following modification of his views as expressed with Mr. F. W. HARMER, in the Introduction to the first Supplement to the Crag Mollusca:—

"Now, if we bear in mind that during Stage II. [Lower Glacial period] the submergence of the region to the north and west of the Crag estuary,

* See Modification of Mr. Wood's views, p. 37.

† See H. B. Woodward, *Proc. Geol. Assoc.*, vol. ix., p. 111.

‡ This is found in abundance in the shelly sand (called Weybourn Crag or Norwich Crag by most geologists) on the Cromer and Weybourn Coast, beneath the Rootlet-bed or so-called Forest-bed.

which had been land during the accumulation of the Crag beds, took place, and that the sea-bed thus formed lay directly in the new path which the ice took in consequence of the change of inclination, viz. along the west of the Wold and towards Sheet 67, in which these remains for the most part occur, it is easy to see that such remains are those of Mollusca which lived during Stage II. [Lower Glacial], and during so much of the present stage [Middle and Upper Glacial combined] as elapsed previous to their removal; and may not therefore be altogether synchronous with each other, though all of Glacial age, being the remains accumulated on the sea-bottom in some locality favourable for their existence during this time, which the ice in its advance ploughed out and sent on their travels. Thus it is that this shelly band, like the débris of the clay itself, occurs only within some three or four feet of the junction of the sand and gravel c [Middle Glacial] with the Chalky Clay. It is generally also immediately beneath or associated with a vein of chalky gravel."*

MR. WOOD completes his observations in the "Third Supplement to the Crag Mollusca" with the following statement:—"I should add that though, to avoid confusion in this explanation, I have adhered to the term Middle Glacial, this formation is (in the view to which the continued study of the subject has brought me) merely the marine accumulation which was synchronous with the moraine of the land ice which is represented by the chalky clay; and the precise mode in which the two were accumulated, according to my view, is traced in detail in the Memoir just referred to" [as given above.]+

The above extracts are given as conveying MR. WOOD's last opinions on a subject he had given so much study and attention to. It is to him and to his father that geologists are mostly indebted for the long list of Molluscan remains which have been obtained from this deposit (*see* pp. 93-95).

It will be observed that MR. WOOD was of opinion that these Molluscan remains occur "only within some three or four feet of the junction of the sand and gravel with the Chalky Clay," and as a "shelly band." And, assuming this to be the case, he then endeavours to explain how it is that they only occur in that position.

The Molluscan remains, however, instead of being confined to any particular band, occur, here and there, at all horizons in the sands and gravels. During my investigations in the district, they were observed in profusion at the base of the deposit as well as near the summit, and in various intervening places. They are to be seen occupying these various horizons in the cliffs at Kessingland, Pakefield, Corton, and Gorleston, where the deposit varies from 30 to 50 feet or more in thickness. And they are also to be seen occupying a similar position in these sands and gravels in numerous inland pit-sections.

They occur, likewise, in profusion at different horizons in the sands and gravels filling the basin-shaped hollows in the upper part of the Cliff westward of Cromer.‡

With regard to the List of Mollusca (pp. 92-95), it should be remarked that two localities, Corton and Billockby, have yielded so large a number of species on account of the assiduous manner

* *Quart. Journ. Geol. Soc.*, vol. xxxvi., pp. 484, 485 (1880).

† *Palaontograph. Soc.*, 1882, p. 24.

‡ *See* The Memoir on the Geology of the Country around Cromer.

in which they have been searched. Were other localities explored with the same care and diligence, such as the large pit at Lound, and that near Caister Castle, there is every reason to think that they would be found quite as prolific; and possibly some species not mentioned in the list might be obtained.

In nearly every inland pit-section of these sands, from the coast at Corton and Gorleston to Burgh Castle, Molluscan remains have been observed in profusion, as well as elsewhere, sometimes giving the sand a Crag-like appearance.

On the Coast at Kessingland and Pakefield.

In the Explanation to the Cliff-section of this portion of the coast the deposit has been thus described:—"This sand is mostly of a fine siliceous nature and of a light buff colour, but whitish and brown in places. In some parts it is very finely stratified, and horizontally and evenly bedded; in others, it is much false-bedded. Although it is often devoid of pebbles or gravel, patches of pebbly sand and gravel sometimes occur; this is particularly the case on either side of Pakefield Lighthouse Gap, and between that and the second Gap, and north of the latter; and also in various places at the base of the bed for a few feet upwards from the Rootlet-bed and other underlying deposits. Frequently where the sand presents a whitish appearance, numerous chalk-grains may be observed intermixed with the siliceous sand. Many fragments of marine shells are also occasionally to be observed, particularly in the pebbly and gravelly portions of the sand; they are abundant in places from Pakefield Lighthouse Gap to the *Unio*-bed, also further south in the cliff where the patch of Pebbly Sand is shown on the Section, and elsewhere. The shells mostly present a much water-worn appearance."

Ripple-marks are occasionally to be observed in these sands; they were beautifully shown in a lenticular bed of grey marly clay where marked on the Section.

On the Coast at Corton and Gorleston.

As some geologists and collectors of fossils have referred to the cliff on this coast as if a portion of it was in the parish of Hopton, mentioning "Hopton Cliff,"* it is necessary to state that a narrow strip of the parish of Corton at present unites with the parish of Gorleston, and extends in front of a portion of the parish of Hopton; and that no part whatever of the latter parish extends to the sea-coast. If the rapid erosion of the cliffs that is now taking place continues, the narrow strip of the parish of Corton will soon be entirely swept away, and the eastern part of the parish of Hopton, at present in its rear, will then become exposed to the ravages of the sea, and form a sea-cliff.

* See 1st Supplement to the Crag Mollusca, Palæontograph. Soc. p. 22.

The following description is from the Explanation of the Section (Sheet 128):—

"A fine section of this formation is exposed in the Cliff at Corton, and extends from there to Gorleston breakwater. The sand is mostly of a buff colour, well stratified and in places much false-bedded, and similar in character to that exhibited in the equally fine cliff-section at Kessingland and Pakefield. In places, however, between League Hole and Gorleston, the buff sands are much intermixed with those of an orange colour, which has led to some mistakes as to their age."

"The finely stratified, and in places laminated, unctuous grey clay that occurs in the middle of the buff sands, as shown on the Section south of Corton Gap, is probably of similar age and character to the clay that was excavated about one mile further south, at Gunton, for the manufacture of "Lowestoft China." See p. 96.

"Numerous fragments of marine shells occur in the sands at different horizons and localities in this cliff, mostly in a much rubbed or water-worn condition; sometimes they extend from near the base to within a few feet of the top of the cliff, as they have been observed about 200 yards south of Gorleston breakwater; and sometimes they occur intermixed with the patches of gravel immediately overlying the stony Loam or Lower Boulder Clay, as south of Corton Gap and elsewhere. Occasionally beds of sand occur having marine shell-fragments diffused throughout them in a finely comminuted state, as near Gorleston breakwater. Whole shells also occur, but they are very rare as compared with the fragments." The shells collected are named in the list on pp. 93-95.

South of Gorleston the sand is about 50 feet thick, with occasional impersistent reddish-brown loamy bands, generally from 2 to 12 inches thick. Patches of white pebbly sands occur in places. The shell-fragments, which are much more abundant in some spots than in others, are very plentiful from 3 or 4 chains south of the breakwater for a distance of about 20 chains, and occur from about the middle part of the cliff upwards, to within 5 feet of the top. In one place, about 15 chains south of the breakwater, the sand was shelly for a thickness of 9 feet, and had in places the appearance of Crag, the fragments being very numerous, and particularly in the white pebbly patches. Some of the loamy bands contained finely comminuted shell-fragments, whereas, in other places, fragments, from an inch to more than 2 inches in length, of such shells as *Cyprina islandica* and *Mya arenaria* were seen mixed with smaller fragments, all water-worn. The shells found are named in the list on pp. 93-95.

Local Details. North of Yarmouth.

West Somerton.—In a pit about a quarter of a mile N.W. of the church, on the southern side of the road, about 18 feet of sand was shown, with a bed of brown loam in the centre containing concretions. The sand above the loam is brown and about 8 feet in thickness; and that beneath the loam is very light buff, and white in places, with numerous chalk grains.

Sand is shown between Boulder Clay and loam in the pit described on p. 30.

East Somerton.—Sand is exposed on the road-side to the east of the plantation, about half a mile W.S.W. of Winterton Church.

Martham.—About a quarter of a mile E. of Martham Hall, 10 to 12 feet in thickness of buff sand is exposed in a pit on the northern side of the road leading to Gibbet Hill. There are some thin irregular and impersistent beds of more or less indurated, reddish-brown sand similar to those that occur in the buff sands in the cliffs at Gorleston, Pakefield, &c., as well as in numerous inland pits. The sand is much false-bedded; and in the lower part, in places, very small pebbles occur, together with some ferruginous concretionary nodules. From 2 to 3 feet of reddish-brown loam, containing large subangular and angular flints, irregularly overlies the sand and forms the sub-soil in places.

At Damgate, about three eighths of a mile N.N.E. of Martham Church, a pit occurs on the eastern side of the road, showing well-stratified buff sand, 9 feet in thickness. On the western side of the road, where the ground is at a lower level, reddish-brown loam is exposed in a small pit.

In a field, a little further to the east, another sand-pit occurs, where the thickness shown is about 16 feet.

In the railway-cutting between the station and Martham Hall 4 feet of very light buff sand was exposed, together with a patch of reddish-brown loamy clay and sand.

Hemesby.—In the railway-cutting about three quarters of a mile S. of the church about 6 feet of Boulder Clay (consisting of reddish-brown loam, near the surface, and of more or less chalky grey clay, at the base) overlies about 15 feet of buff and brown sand, in places very finely stratified and much false-bedded. The Boulder Clay apparently lies unconformably on the sand.

Two other sections here are described on pp. 31, 52.

Ormesby St. Michael's.—About 9 feet of buff sand was exposed in a pit three eighths of a mile S. of the church, the total thickness not being shown.

In a pit three eighths of a mile E. of the church, on the southern side of the road, the following section was seen :—

		FEET.
Glacial Drift	Boulder Clay, varying from light to dark grey	15
	Brown loam and clay interstratified with light-buff sand	3
	Light-buff sand	7

The description of other sections at Ormesby St. Margaret's will be found on pp. 32, 53.

Rolleby.—At the clay-pit, a quarter of a mile W.S.W. of the church, on the southern side of the road, where there was a greater thickness of Boulder Clay on the slope of the hill than on the top, the following section was exposed :—

Irregular capping of a little dark red and chocolate-coloured loam and sand, more or less piped into the clay beneath.

Glacial Drift	Boulder Clay, bluish-grey; with a small patch of buff sand; base sharply defined; resting in an undulatory manner on the sand; 15 feet.
	Lenticular patch of very coarse flint gravel, with a few sand-stone boulders and ferruginous concretions; 24 feet long, up to 2 thick: in places hardened into a conglomerate at top, in others at the bottom, and sometimes at both, in such a way as to enclose loose gravel.
	Lenticular patch of orange-coloured sand, on the southern side; 17 feet long and up to 1½ thick.
	Very fine buff sand, with chalk grains; 6 feet.

It is doubtful whether the 5 feet of loam next beneath the sand, in the well here (see p. 81), belongs to this division, or to the underlying stony loam.

Filby.—In a large pit, now much filled-in and overgrown, five eighths of a mile N.E. of Mauthby Church, on the southern side of the road, the sand is of considerable thickness; buff, brown, and white; and, in places, contains numerous fragments of shells. (*Cardium edule*, Linn. *Turritella incrassata*, Sow.)

Nine feet in thickness of buff sand, containing fragments of marine shells, were exposed in a small pit five eighths of a mile N.N.W. of Caister Castle.

Another section is described on p. 54.

Thrigby.—Two sand-pits occur, a quarter of a mile S.S.E. of the church, at the second fork in the road; one on the northern side of the road, and the other on the southern.

A pit a quarter of a mile S. of the church, on the western side of the road, showed 9 feet of buff sand, a little loamy in places, containing some more or less indurated ferruginous sandy bands, and also two or three irregular thin beds of brown and grey clay, mostly from an inch to 3 inches in thickness.

Runham.—A small pit $1\frac{1}{2}$ miles E. of the church, and $\frac{1}{4}$ mile W. of Decoy Farm, on the sloping ground adjoining the alluvium, showed 9 feet of sand, well stratified, and with the bedding more or less inclined, buff, with some impersistent ferruginous bands, and with a loamy bed, about 6 inches thick, 8 feet down, which was shown to die out in the pit.

Stakesby.—There is a pit three quarters of a mile W. of Runham Church, at Herringby, north of the road leading to Runham, in which the sand is buff, and contains several irregular, impersistent, more or less indurated, reddish-brown beds, usually from 1 to 6 inches in thickness, and a few lenticular patches of gravel, consisting of small pebbles. The total thickness was 12 feet, and the sand was overlain by about 3 feet of stiff brown loam, with scattered large angular flints.

Some large gravel-pits occur at Hilbro' Hole, about a mile and an eighth W.N.W. of Runham Church, where stones are obtained for the metalling of the parish roads. Coarse gravel overlies brown and buff sand, with pebbly gravel in lenticular patches. This sand is well stratified, and contains thin, impersistent, more or less indurated, reddish-brown beds. The gravel has a disturbed appearance, and consists mostly of large subangular flints, from 4 to 12 inches in length, mixed in places with reddish-brown sand, and thickest apparently on the slopes of the hill, where in one place it was 9 feet thick. This gravel may possibly be of a different age to the buff sand containing pebbly gravel, on which it lies, and with which it is apparently much mixed at its junction.

On the northern side of the hill, in a little pit close to the road opposite the plantation on the marshes, numerous fragments of marine shells were seen in the pebbly gravel; and some also in the lower part of the large old pit a little further south. Quartz pebbles, and two small well-rounded boulders of grit, 4 inches in diameter, were the only rocks besides flint observed in the gravel.

West Caister.—In an old pit, now mostly overgrown, on the eastern side of the road, about 200 yards N. of Caister Castle, very shelly, buff, slightly gravelly and obliquely-bedded sand, 15 feet in thickness, was exposed, under about 6 feet of Boulder Clay. In one part of the pit was a mass of indurated sandy breccia measuring $5 \times 4\frac{1}{2} \times 2$ feet; this probably came from the junction of the sand with the Boulder Clay, such hardening being a well-known occurrence in many other localities. The sand, in places, owing to the numerous fragments of shells it contained, presented somewhat the appearance of Crag. The list of these shells is given on pp. 93-95.

East Caister.—During the construction of the railway-cutting between California and East Caister the following section was exposed on the eastern side for about 7 or 8 chains:—

	FEET.
Brown and buff sand, loamy near the surface	3
Gravel, containing shell-fragments in patches (for list see pp. 93-95)	2 to 3
Buff sand, containing some impersistent bands of reddish-brown loam	9 to 14

The bed of gravel was about 3 chains in length, mostly consisted of flint and quartz pebbles, with occasional quartzite, flint and grit boulders generally from 4 to 6 inches in diameter, together with some pieces of chalk covered with dendritic markings. A large quantity of this had been used for ballast for the permanent way, and it is possible that eventually the whole bed, which caps this little hill, will be excavated for that purpose.

A mile N.W. of East Caister Church, at Nova Scotia Farm, in the plantation on the eastern side, immediately behind the farm-buildings, the following section was exposed in a pit:—

Boulder Clay, with brown loam irregularly in the upper part; 8 feet.
 Sand, buff, very fine, and very free from pebbles; with a few thin, impersistent, buff, loamy seams in places; and some indurated sand about a foot down; 15 feet.

Local Details. South of Yarmouth and around Lowestoft.

Burgh (Castle).—Excavations, showing good sections, occur near the Cement Works and in the adjoining brickyards, south of Burgh Castle; and also, in places, along the escarpment between the church and the ruins of the Castle. In the large excavation south of the flag-staff near the Cement Works, a section showed about 10 feet of buff sand, containing some reddish loamy bands, chalk-grains, and fragments of shells, amongst which were *Cardium edule*, *Cyprina islandica*, and *Tellina balthica*. At the southern end of this section, the sands were contorted near the wedge of Boulder Clay (see pp. 55, 56); and, in places, in the lower part, were false-bedded and very pebbly, the pebbles being almost entirely of quartz and of flint.

In the adjoining brickyard, further south, the sands overlying the stony loam varied from 4 to 12 feet in thickness, were well stratified, and false-bedded in places, with a few contortions here and there, and were sometimes very pebbly, the pebbles again consisting of quartz and of flint.

Bradwell.—In the railway-cutting half a mile N. by E. of the church, buff sand, containing numerous fragments of shells, is exposed under Boulder Clay.

In 1862 MR. C. B. ROSE described this cutting as follows:—"From the south-town side of the harbour [Yarmouth] starts the East Suffolk Railroad and about one mile from the station, in a cutting of the line, two thin beds of re-deposited Crag shells are exposed. The section at the spot, examined by me, is from ten to twelve feet in depth. At five feet from the surface is a deposit of the shells, chiefly in fragments, in a light-coloured sand; and four feet below the above occurs a second deposit of shells, of the same character as those in the upper beds; each bed is but from three to six inches in thickness; a gravelly sand, composed of small angular flints and pebbles, lies above, between, and beneath the two beds of shells, as far as the strata are opened by the cutting."* The list of the shells found here is given on pp. 93-95.

Gorleston.—In a clay-pit a little more than half a mile N.W. of the church, in a field on the northern side of the road, 5 feet or more of laminated white and buff loam and sand, contorted in places, underlain 6 feet of Boulder Clay, some buff sand intervening on one side.

Lound.—In the large pit marked on the Map from a quarter to three eighths of a mile S.W. of the church, the following section was exposed:—

Dark grey Boulder Clay, with many boulders of chalk and flint, with but few of other rocks, the most noticeable of these being Lias limestone and shale; some of the boulders, particularly those of chalk, much rounded and striated; 20 feet.

* *Proc. Geol. Assoc.*, vol. i., no. 8, pp. 192, 193 (1862).

Sand, buff, with here and there patches of white and orange-coloured. Many impersistent seams and patches of pebbly gravel, the pebbles mostly consisting of flint and of quartz. Fragments of marine shells diffused throughout, and particularly abundant in the gravel. Occasionally, but rarely, whole shells occur; two hours search, yielded two; 15 feet.

The following shells have been identified:—*Pectunculus glyceris*, *Tellina crassa*, *T. obliqua*,? and *Purpura*?

Herringfleet.—In a pit W. of Blockley Hall Farm, about 12 to 15 feet in thickness of light-brown sand, was exposed and shown to be overlain by grey Boulder Clay on the south-eastern side.

Another pit occurs just south of the above farm, where a large quantity of Boulder Clay has evidently been excavated. Under this about 10 feet of buff sand was exposed, containing numerous fragments of marine shells in places, especially in the upper part, and underlying two or three irregular bands of indurated sand, which latter occurred near the junction of the sand with the clay, as observed in many other localities.

Somerleyton.—A large sand-pit at East Grove Farm, half a mile S.S.W. of Lound Church, showed 4 to 6 feet of Boulder Clay, with much brown loam irregularly intermixed, especially in the upper part, over buff sand, 20 feet deep.

Blundeston.—About half a mile E.S.E. of the church, in a pit at the south-western corner of Cockshoot Wood, 8 feet of buff and whitish sand, containing numerous chalk-grains, was exposed, under 7 feet of grey Boulder Clay.

In a large pit three-quarters of a mile E.N.E. of the church, there is from 8 to 12 feet of Boulder Clay over buff and white sand, shown to the depth of 12 feet.

A large sand-pit, five eighths of a mile N. of Blundeston Church, on the southern side of the road, showed:—

	FEET.
Boulder Clay	2 to 4
Sand, light-buff and white, very finely stratified, with a few thin bands of grey loam: one band, from 4 to 9 inches thick, and resembling pipe-clay, occurred along a wavy line about 15 feet beneath the clay	25

The wavy appearance above described is noticeable in the sands in many other localities.

The following was stated to be the section of a dead well at High House, to carry away waste water, &c.:—

Boulder Clay, 16 to 18 feet.
Sand and gravel, 22 feet.

Corton.—A pit three eighths of a mile N. by W. of the church, on the eastern side of the road, showed 13 feet of buff sand, finely stratified and false-bedded in places.

A large sand-pit five eighths of a mile W.S.W. of the church, near the fork in the road, on the eastern side, gave the following section:—

Light-coloured Boulder Clay, resting unconformably on the bed below;
6 to 8 feet.
Sand, buff, but at the bottom part chiefly white; 12 to 15 feet or more.

In the middle part of the section there was some very finely laminated buff loam interstratified with the sand, the lamination presenting a very wavy appearance.

From near League Hole to a distance of about a mile northward the sands, as shown in the cliff, are unusually ferruginous, and are of a reddish-brown or orange-colour, intermixed in places with light-buff. The greater quantity of this reddish-brown sand is in the upper part of the cliff, but in places it reaches to the bottom. The whole is well stratified, and lenticular patches of loam occur in the upper part of the cliff about 15 to 20 chains north of League Hole.

These orange-coloured or reddish-brown sands are clearly shown to pass horizontally, on either side, into the ordinary light-buff sands, which look almost white here in comparison with the others.

Gunton.—Buff sand is shown to occur beneath Boulder Clay in the pits a quarter and a third of a mile respectively east of Gunton Hall. Also in a third pit about half a mile east of the Hall, where the sand is from 5 to 6 feet in thickness, and underlain by fine, brown loam.

In the pit W. of the gravel-pit and brickyard about half a mile N.N.E. of the Church, and on the northern slope of the valley and the western side of the road, the following section was exposed :—

		FEET.
Plateau Gravel.	Gravel, Sand, and Loam	6
Glacial Drift	Dark bluish-grey Boulder Clay, with many boulders of chalk and flint, and a few of Lias limestone and other rocks, which were very much striated	6
	Laminated light-buff loam, sandy in places	7

Lowestoft.—At the brickyard three quarters of a mile N.W. by W. of St. Margaret's Church, on the western side of the road, the following section was exposed :—

		FEET.
Plateau Gravel, &c.	Coarse flint gravel, reddish-brown loam, and reddish sand	6
Glacial Drift	Dark grey and black Boulder Clay, with many striated and fossiliferous boulders of various rocks; resting sharply and evenly on the bed beneath	16 to 20
	Sand, clean, buff, stratified, and slightly false-bedded in places	18

In the south-eastern corner of the brickyard a few thin seams of laminated grey clay and brown loam occurred interstratified with the sand; in places they presented a wavy appearance, as did also some of the finely stratified sands in other parts of the pit.

A large gravel-pit occurs seven eighths of a mile W.S.W. of St. Margaret's Church, on the northern side of the road. The gravel mostly consists of flints, is very pebbly, and about 40 feet in thickness. Some clean buff sand, about 6 feet thick, occurred in the upper part, interstratified with the gravel. I was informed by the workmen that this gravel was underlain by light-brown sand. Some of the gravel in the upper part is probably Plateau Gravel.

In another gravel-pit, a few yards from the above, 20 feet in thickness of flint-gravel, containing lenticular patches of sand and clay, was exposed. The gravel was shown to be coarse in places near the top, and particularly so at the bottom, where it rested on whitish sand.

Light-yellow sands, false-bedded in places, were well exposed in the railway-cutting north of Lake Lothing, and, towards the Harbour, contained gravel in the upper part.

A pit immediately south of the railway-cutting, about a quarter of a mile E. of Mutford Railway Station, on the slope of the ground north of Lake Lothing, exposed 18 feet of gravel with an eroded plane in the middle. The gravel was of the nature of shingle, with a little buff sand in places, and with some large flints, "paramoudras" 2 feet in diameter, etc. That above the eroded plane (which may be of "Plateau" age) was of a light colour, and that below was much stained with ferruginous matter. The eroded plane however may possibly only be due to current-bedding.

A section nearly half a mile south of St. Margaret's Church is described on p. 56.

Oulton.—In a pit half a mile S.E. by S. of the church, on the sloping ground north of Oulton Broad, the gravel is of the nature of shingle, consisting almost entirely of flint pebbles, intermixed with subangular flints averaging about six inches in diameter, together with a few boulders of girt and of other

rocks. It is reddish-brown, very ferruginous in places, 9 feet in thickness, and overlies brown sand.

At the pit about 40 yards N. of the windmill, south of Mutford Railway Station, the gravel consists almost entirely of flint pebbles, with a few scattered large flints, some being about a foot in length; it also contains a few patches of brown and buff sand, and is stained black and chocolate-colour in places. It had been excavated to a depth of 14 feet.

At another pit to the E. of the windmill, about 100 yards south of Mutford Railway Station, close to the railway to Beccles, the gravel consists of flint pebbles with some scattered large flints, some measuring 18 inches in length; and is similar in character to that exposed in other pits in the neighbourhood of Oulton, containing some black and chocolate-coloured stains in it, etc. From 4 to 7 feet down a very irregular plane of erosion was clearly shown; immediately beneath which, in the centre of the pit, a large lenticular patch of stratified buff sand was exposed, in one part 5 feet thick. The pit had been excavated to a depth of 25 feet, but the total thickness of the gravel was not shown.

Another section here is described on p. 57.

Aldeby.—A small pit at the back of a farm-house, a few yards E. of the railway-station; showed 15 feet of buff sand, in places with numerous fragments of marine shells, underlying about 4 feet of Boulder Clay.

In a large pit half a mile S. of the railway-station, in the middle of a field on the eastern side of the railway, 14 feet of buff sand was exposed, under 10 feet of grey Boulder Clay, with a boulder of Lias limestone about a foot in length, containing fossils. Some of the sand, near its junction with the clay, was in an indurated condition. Similar indurated sand is exposed on the eastern side of the railway immediately south of the cottage at the level-crossing, nearly three eighths of a mile S. of the railway-station; where three feet of Boulder Clay is shown overlying the sand.

Much pebbly gravel occurs in the immediate vicinity of Aldeby Church. About 300 yards S.E. of it, a gravel-pit, in the middle of a field on the eastern side of the road, showed 10 feet of gravel, very similar to shingle in appearance, with a little light-brown coarse sand interstratified in places. The gravel consists almost entirely of flints, with some pebbles of quartz and quartzite intermixed; but the latter were few in number compared with those of flint. A few large subangular flints occurred in places, some from 1 foot to 1 foot 6 inches in length.

About 15 feet of buff sand was shown to underlie about the same thickness of dark-grey Boulder Clay in a large pit three eighths of a mile S. of Wheatacre Church. The junction was not clearly seen, from the sides of the pit being overgrown and obscured by talus.

A sand-pit a mile N. of Wheatacre Church, on the western side of Wheatacre Marsh, gave the following section:—

Grey Boulder Clay; 2 feet.

Buff sand, false-bedded in places; 12 feet.

In a large gravel-pit at Burgh Common, on the eastern side of the road, a mile S.E. by S. of Wheatacre Church, gravel and well-stratified sand occur variously intermixed. The gravel is very pebbly as well as subangular in places, and of various degrees of fineness; on the whole, the stones are from about $\frac{1}{2}$ inch to 3 inches in length, and mostly consist of flints with pebbles of quartz and of quartzite. Occasionally, large flints occur, 8 inches and more in length. The sand is very similar to that in the cliffs at Gorleston, being buff with interstratified bands of reddish-brown; in some places it is of an orange-colour. The gravel was exposed at all horizons, from top to bottom of the pit, interstratified with the sand, the whole from about 30 to 40 feet in thickness, and not bottomed.

A pit seven eighths of a mile S. of Wheatacre Church, on the western side of the road, showed about 8 feet of coarse gravel intermixed with pebbles, presenting an unstratified appearance, and somewhat similar in character to the gravel near the top of the hill-slope above Aldeby brickyard. It was reddish-brown, and consisted almost entirely of flints with a few quartz pebbles inter-

mixed, mostly from $\frac{1}{2}$ to 3 inches in length, with the exception of some scattered subangular flints, about 8 inches in length.

In another gravel-pit nearly opposite to the above, on the other side of the road, at least 10 feet in thickness of gravel was exposed, with a lenticular patch of stratified brown sand, 30 feet in length and 3 feet in depth at the most, in the upper part. The gravel in these two pits may belong to the Plateau Gravel.

Adjoining a gravel-pit S.E. of Aldeby Hall, but lower down the sloping ground, a pit showed 8 feet of buff sand.

In a pit a little N.E. of Aldeby Church, 12 feet in thickness of coarse gravel was exposed, which may be Plateau Gravel.

Wheatacre.—From 8 to 9 feet of very fine buff sand was exposed, underlying from 9 to 12 feet of dark grey Boulder Clay, in a pit in a field three quarters of a mile S.E. of the church.

Burgh St. Peter.—A large pit, nearly half a mile E.S.E. of Wheatacre Church, shows, beneath about 10 feet of Boulder Clay, from 15 to 20 feet of buff sand, with many chalk grains, and numerous fragments of marine shells near the bottom part, some in a comminuted state. A much striated boulder in this pit measured $4\frac{1}{2} \times 2 \times 1\frac{1}{2}$ feet.

A pit a mile E. by N. of Wheatacre Church, on the southern side of Orford's Farm, gave the following section:—

Glacial Drift. Sand, buff, with a little reddish-brown loam in places; 13 feet.

Pebbly Series. Gravel, more or less of an orange-colour, having the appearance of shingle, and mostly consisting of flints and quartz pebbles; 10 feet.

In a sand-pit on the slope of the hill W. of the parsonage, and on the southern side of the road, a little more than a mile W.S.W. of Burgh St. Peter's Church, the section was as follows:—

Grey Boulder Clay, 3 to 4 feet.

Buff sand, very clean, 8 to 9 feet.

An interesting section was exposed in the large gravel-pit three eighths of a mile S.W. by W. of Burgh St. Peter's Church, on the highest ground in this part of the small promontory, the beds being as follows:—

Plateau Gravel. Consisting almost entirely of flint pebbles, with a few of quartz, varying from about half an inch to 3 inches in length: a few subangular flints, some 8 inches in length, sparsely scattered throughout. Contains very little sand, is distinctly bedded, at an angle of 30° or more towards the south-east, and rests unconformably against the Glacial gravel; 20 feet.

Glacial Drift. { Gravel composed of similar materials to the above, and, like it, reddish-brown; but horizontally bedded.
A considerable quantity of horizontally-stratified false-bedded sand, varying from reddish-brown to white, on the northern side.

Where the sand occurred, the Glacial Gravel was overlaid in two places by lenticular patches of Boulder Clay, mere remnants, from 2 to 3 feet thick, and about 15 feet long.

Other sections at Burgh St. Peter are described on p. 57.

Carlton Colville.—About 10 feet in thickness of buff sand was exposed in a pit a little more than half a mile S.E. by S. of the church.

At the brickyard, half a mile E. of the railway-station, the following section occurs:—

Dark-grey and black Boulder Clay, with less chalk than usual; boulders abundant, one, of hard sandstone, measuring 5 feet by 2; 7 to 12 feet.

Sand, very clean, finely stratified, in places much false-bedded, and varying in colour, yellow, white, and buff being the prevailing tints; 28 (in well to 40) feet.

A few fragments of marine shells were observed, and were particularly noticeable in the white portions of the sand. A little laminated loam and

dark red sand occurred in a few places in the upper part, near the junction of the sand with the Boulder Clay; where, also, some indurated sand occurred in irregular shaped masses. Possibly, some of the sands at the base in the well here (p. 83) may belong to the Pebbly Series.

In a pit immediately north of the railway, and about three eighths of a mile eastward of the railway-station, the following section was exposed:—

Pebbly and sandy gravel; 4 to 6 feet.

Buff sand and grey loam interstratified, both beautifully laminated, and very similar to some beds at Woolpit, near Bury St. Edmunds; contorted in one place in the middle part of the pit, and containing some small ferruginous nodules; 10 feet.

Another pit, showing a somewhat similar section, occurs south of the railway.

At a large pit seven eighths of a mile N. of Carlton Colville Church, near the railway, by the cross-roads, the sand exposed in the upper part was buff, and near the top had a little fine gravel intermixed. In the lower part the sand was whitish. The overlying Boulder Clay was from 2 to 4 feet thick.

Another pit occurs about 10 chains S.E. of the above, on the eastern side of the road, where from 2 to 4 feet of Boulder Clay overlaid buff and white sand, with numerous chalk grains.

In a pit three-eighths of a mile W. of the railway-station, on the western side of the road leading to the marshes, the following section was exposed:—

Sandy soil, with quartz pebbles, etc.	-	-	2 feet.
Gravel, mostly consisting of small subangular flints	-	-	6 "
Sand, stratified, buff, with ferruginous stains	-	-	5 "
Sand, white, with ferruginous stains	-	-	3 "

Mutford.—In a sand-pit a little more than a quarter of a mile N.E. of Hulver Bridge, on the northern side of the road, 9 feet of well-stratified buff sand was overlain unconformably by 1 to 4 feet of pebbly gravel, like shingle in places, with a little loam here and there underlying it. The section clearly showed that the adjacent valley had been cut out after the sand was deposited, as the horizontal lines of stratification were sharply cut off on the sloping ground. At the junction of the gravel and sand, both were more or less indurated and cemented together, and were black and chocolate-coloured. Some of the sand on the southern side was grey, interstratified with brown. The gravel consisted mostly of pebbles of flint and quartz, from $\frac{1}{2}$ to 4 inches in length, intermixed with larger subangular flints.

A pit an eighth of a mile W. of the church, on the northern side of the road, showed 10 feet of buff and brown sand, overlain in places by 1 to 3 feet of gravel.

In a gravel-pit three eighths of a mile S.W. by S. of Mutford Church, 6 feet in thickness of fine pebbly gravel was exposed, over sand. Both were more or less indurated and cemented together with ferruginous matter, and stained black in places.

The following section was exposed in a pit nearly three quarters of a mile S.E. of Barnaby Church:—

Grey Boulder Clay; 5 to 6 feet.

Very light buff sand containing comminuted fragments of shells in the lower part; 14 feet.

[The following notes of an excavation made in Mutford Wood in 1870, before Mr. Blake surveyed the district, are taken from an account by Mr. H. K. CREED.*

"In a small natural hollow on the south-west side of the wood, close by the road . . . from . . . Carlton Colville to . . . Mutford," a gamekeeper in digging, "came upon some large stones of a peculiar shape, and they were subsequently excavated. All the stones were found imbedded perpendicularly in the post-tertiary formation of the district, their ends nearest the surface being about three feet below it, and all upon the same level. Some of the stones are not more than three feet in length, others nearly seven. The top soil of the hollow was loam to the depth of about two-and-a-half feet; below this is pure yellow sand, lying in horizontal strata. In the loam above

* *Proc. Suffolk Inst.*, vol. iv., no. 5, p. 244, 2 plates (view and plan). 1872.

the stones were found bits of . . . pottery, some bones, and . . . a few small oyster shells."

PROF. EDGWICK saw these stones "and at once pronounced them to be natural sandstone formations, produced probably by infiltration of [carbonate of] lime."

This is an interesting case of the cementation of the sand, &c. beneath the Boulder Clay, which is not uncommon in some other districts.

The view and plan show eight separate masses of columnar stones, (in three cases, joined groups of two or more,) in a semicircular space of $17\frac{1}{2}$ feet diameter.—W. W.]

Worlingham.—A sand-pit half a mile S. of the church, on the western side of the road, gave the following section :—

Boulder Clay ; 3 feet.

Sand, slightly false-bedded in places, very light buff, and containing numerous chalk grains ; 15 to 20 feet.

Ellough.—A pit at the south-eastern corner of the wood, a little more than a quarter of a mile W. by N. of Hulver Bridge, exposed the following section :—

Grey Boulder Clay ; 12 feet.

Buff sand, with chalk grains in places ; 11 feet.

In a sand-pit on the western side of Warren's Lane, a little more than half a mile W. of Hulver Bridge, the following was the section :—

Light-grey Boulder Clay ; 0 to 5 feet.

Sand, very light buff, in places containing numerous grains of chalk and some pellets of hard marly clay ; much false-bedded, particularly in the upper part, where the lines of stratification were sharply cut off by the clay ; 9 feet.

The Boulder Clay was thus shown to be unconformable to the sand, and to wrap over it partly down the gentle slope of the valley. Immediately beneath the Boulder Clay the sand was here and there indurated into irregular masses of sandstone.

A sand-pit occurs nearly three quarters of a mile N.W. of Hulver Bridge, on the western side of Warren's Lane, with the following section :—

Grey Boulder Clay ; 6 feet.

Buff sand, containing numerous chalk grains in places ; 20 feet.

Rushmere.—A sand-pit, much grown over with brushwood, on the northern side of the farm-buildings adjoining the road, five eighths of a mile S.E. of the church, shows about 15 feet of whitish and buff sand, false-bedded in a few places. About 6 feet or more of Boulder Clay overlaid the sand at the northern end of the pit.

Gisleham.—About 10 feet of buff sand was seen, underlying from 9 to 10 feet of Boulder Clay, in a pit seven eighths of a mile S. by W. of the church. There was a boulder of gneiss in the clay 4 inches in length, and one of flint measuring $1\frac{3}{4}$ by $1\frac{1}{2}$ feet.

Kessingland.—The following section was exposed in a sand-pit half a mile S.S.W. of the church, on the northern side of the road.

Glacial Sand, buff, and pebbly in places ; 6 feet.

Chillesford Beds. Very finely stratified, micaceous, grey clay, brown loam and sand, more or less laminated ; 3 feet.

At a small brickyard a little more than three eighths of a mile E. of Kessingland Church, on the slope of the hill north of the road, the loam, from which the bricks were made, was a lenticular patch in the sand, 4 feet in thickness.

About 10 feet of whitish and very light-buff sand was exposed in a sand-pit half a mile S.W. of Kessingland Church.

Nearly a mile S.S.E. of Gisleham Church, 12 feet of very light buff sand was shown, underlying 9 feet in thickness of Boulder Clay, in a pit.

A large sand-pit near the above, and about three quarters of a mile N.W. of Kessingland Church gave the following section :—

Boulder Clay ; 8 to 10 feet.

Sand, very light buff and whitish ; 20 feet.

CHAPTER VII. GLACIAL DRIFT (*continued*).

BOULDER CLAY. [UPPER GLACIAL, OF WOOD.]

General Remarks.

This well-known and characteristic Glacial deposit constitutes the heavy lands of Norfolk, Suffolk, &c.; and occupies most of the high ground in the area north of Yarmouth, as well as of that to the south, and around Lowestoft, except where covered with Plateau Gravel. The manner in which it occurs is shown on the Geological Survey Map, which to a great extent tells its own story, and this is more especially the case when studied in connection with the adjoining maps. Moreover, the geological mapping of the ground proves this Boulder Clay to be a continuation of that widespread deposit which covers so large a portion of East Anglia and of adjoining districts. In the southern portion of the area, at Aldeby and Worlingham, westward of Lowestoft, it is shown to unite with the main mass that has been traced continuously to Ipswich, Stowmarket, Attleborough, East Dereham, Swaffham, and so on, extending, if not quite continuously, at any rate in large outlying masses, to a considerable distance around the Fens, to the south, west, and north-west of the Wash.

In this district the position of the outlying masses of this clay on the high ground to the north of Yarmouth, surrounding Ormesby, Rollesby and Filby Broad, and also the position they occupy around Lowestoft, clearly demonstrates the immense amount of denudation the country has undergone since this Boulder Clay was deposited; the disconnected manner in which portions of it now occur in the district being apparently due to so much of the deposit having been swept away.

It is, on the whole, very uniform or homogeneous in character. The greater proportion consists of subangular and rounded fragments and boulders of chalk and of flint, thickly clustered together in an unstratified matrix of clay and marl, as mentioned in the following description of the deposit in the cliffs of this district. As the constituents of which it is made up are for the most part derived from the destruction of a large portion of the Chalk, the term "Chalky Boulder Clay" seems an appropriate name for the deposit. The term "Chalky Clay," as used by the late Mr. S. V. WOOD, jun., is not so descriptive, as it does not imply the presence of boulders, with which the formation abounds. [Other beds of Boulder Clay, however, of a far more local character, are sometimes as chalky as this great deposit, and for this reason it is perhaps inadvisable to use the term chalky. The simple name Boulder Clay, unqualified by any adjective, is really enough.—W. W.] Its greatest thickness in the district is about 35 feet.

It is evident from the various constituents of which this clay is made up, that during its accumulation there must have been an immense amount of erosion of most of the older rocks going on.

No doubt the erosion of the Kimeridge, of the Oxford, and of the Lias Clays contributed largely towards the formation of the argillaceous portion of the matrix, as is evidenced from the abundance of Oolitic fossils* and boulders in the deposit. Boulders of Palæozoic rocks occur, and occasionally also some of igneous and of metamorphic rocks. They nearly all show signs of glaciation, some being deeply grooved as well as striated; they are also much rubbed, and I have seen a few more or less polished. They are seldom to be seen larger than from 3 to 4 feet in length, the greater quantity being smaller.

Now and then lenticular patches of buff sand are to be observed in this Boulder Clay; but, as a rule, they are not common. (Three such at Kessingland are depicted on the Cliff-Section.) Whereas, in portions of the Lower Boulder Clay or Lower Glacial Loam (not on the coast at Corton, but inland) irregular patches of buff sand, frequently containing marine shell-fragments, are often to be seen.

Not a trace of any shell-fragment, either of the age of the deposit or derived from any of the Crag or Drift deposits, has yet been detected in this Boulder Clay, so far as I know, although frequently searched for. In this respect, as in others, it differs considerably from the Lower Boulder Clay or Loam, which frequently contains marine shell-fragments.

Wherever the base of the Boulder Clay is exposed, either in inland pit-sections or on the coast, it always shows a remarkably even and sharp plane at its junction with the underlying deposit, as does also the base of the Lower Boulder Clay, the circumstances in both cases for the most part apparently testifying to tranquil deposition.

It may be interesting to observe also that in this district this Boulder Clay rests generally upon well-stratified loose sands (Middle Glacial, of WOOD), which were evidently accumulated in the sea, just as the Lower Boulder Clay also rests on well-stratified loose sands (Pebbly Series) which were likewise evidently accumulated in the sea. And, I think, all the evidence seems to show that both the Upper and Lower Boulder Clay were also formed in the sea; although, judging from the very different nature of their respective constituents, not precisely in the same manner.

That ice-rafts were the means of transport of many of the erratics seems to me the only intelligible theory to account for the presence of such boulders as those of Carboniferous Limestone (between 3 and 4 feet in diameter) in this clay; and of those of basalt, granite, gneiss, and such as are believed to be of Scandinavian origin, in the Lower Boulder Clay.

On the Coast at Kessingland and Pakefield.

"Probably the finest section in England of this wide-spread Boulder Clay is that exhibited in the cliff between Kessingland

* See p. 53 for list of fossils obtained from one clay-pit during a few days' excavation of the clay.

and Pakefield; and the next finest is that at Corton; a very marked and even line, at the junction of the Boulder Clay with the underlying "Middle Glacial" sands, being well shown in both coast sections. . . The clay is mostly bluish-grey in colour, but varies from yellowish-white to dark grey and sometimes black; the whole weathering to a creamy or yellowish-white. Many derived fossils occur in the Boulder Clay, such as *Ammonites*, *Belemnites*, *Gryphæa incurva*, *Serpula*, &c." . .

"Several of the largest boulders measured 3 feet in diameter, and some 3 feet 6 inches. Many of them were much glaciated, being both deeply grooved and striated, the grooves being persistent sometimes along the longest axis of the boulder, whereas the striations frequently crossed in all directions."* The following are the dimensions of some :—

			Ft. in.	Ft. in.	Ft. in.
Carboniferous Limestone	-	-	3	9 × 2	9 × 1 3
			3	0 × 3	0 × 1 0
			3	0 × 2	6 × 1 0
			3	0 × 2	3 × 0 7
			3	0 × 2	6 × 1 0
			3	0 × 1	6 × 1 0
Lias Limestone	-	-	2	3 × 1	3 × 0 7
			2	6 × 1	6 × 0 9
Flint	"	-	2	3 × 1	3 × 0 7
			3	0 × 2	0 × 0 9
Chalk	"	-	2	0 × 2	0 × 0 7
			3	0 × 2	0 × 1 0
Boulder containing much quartz (P formation)			3	0 × 1	6 × 1 0
			3	6 × 3	0 × 2 3

The Boulder Clay is exposed in the upper part of this cliff continuously for a distance of $1\frac{1}{8}$ ths of a mile, its greatest thickness being 30 feet.

On the Coast at Corton.

This formation overlies the Glacial sand in a most regular manner; and for the most part apparently conformably, or nearly so, with an even plane at the junction. It is similar in character to that exposed in the cliff at Kessingland and Pakefield.

The patches of Boulder Clay on either side of League Hole, and in the basin-shaped hollow south of the same, occur in a very abnormal and remarkable manner. On two or three occasions, when the beach-sand had been scoured out by the sea in front of League Hole, Boulder Clay was seen at a short distance in front, on the fore-shore; and I came to the conclusion that in all probability it was connected with the two vertical masses of the same on either side of the gap, the whole forming another basin-shaped hollow, somewhat similar to that shown in the cliff to the south.† The Boulder Clay of this last was observed at a lower level, resting on the stony loam, before the cliff

* Explanation of Horizontal Section, Sheet 128, p. 5.

† See trial-boring at Hopton, p. 85.

was denuded back to its present position, as shown on the Section.* Horizontally stratified light-buff sands occur in the upper part of this basin-shaped hollow, similar in character to those outside; so much so, that when the two ends and other portions of the curve formed by the Boulder Clay are obscured by talus (as they usually are), the impression might be conveyed that it was a lenticular patch of clay in the sands, and of their age.

Several of the largest boulders observed in the clay measured from $2\frac{1}{2}$ to 3 feet in length, and were much grooved and striated.

The Boulder Clay is exposed in the upper part of this cliff, for a continuous length of three quarters of a mile, its greatest thickness being about 13 feet.

Local Details. North of Yarmouth.

Winterton.—An old pit, much grown over with brushwood, &c., in a field nearly three eighths of a mile S. of Winterton Church, a little north of the windmill, showed about 10 or 12 feet of Boulder Clay over buff sand.

In another pit about an eighth of a mile S. of Winterton Lighthouse, from 8 to 10 feet of Boulder Clay was exposed overlying brown sand.

East Somerton.—About a quarter of a mile S.E. of West Somerton Church, a pit showed from 12 to 15 feet of yellowish-white Boulder Clay, over buff sand.

Another pit, showing Boulder Clay, occurs about a quarter of a mile E. of the above, near a plantation.

West Somerton.—Boulder clay was exposed in a small pit, about five-eighths of a mile S. of the church, on the eastern side of the road, a few yards north of the farm-buildings at Blood Hills.

About half a mile W.S.W. of the church, in a small pit a few yards south of the cross-roads, 6 feet of stiff reddish brown stony loam was exposed, containing a little Boulder Clay at the lower part, and irregular lenticular patches in it. This is not an uncommon occurrence where the Boulder Clay gradually thins off: good examples of which may be seen in the cliff sections north and south of Lowestoft; showing the intimate connection of this stony brown loam with the Boulder Clay.

For an account of another pit here, see p. 30.

Martham.—North of the railway and south of Gibbet Hill, about three eighths of a mile E.N.E. of Dairy Barn Farm, is a large pit, now much filled up. An old labourer informed me that clay was dug out of it in 1869 or thereabouts, when a foot only in thickness of Glacial sand was exposed between the Boulder Clay (about 10 feet thick) and loam. Sand was seen, turned out from a burrow-hole, on the western side of the pit, where it had been ploughed over; and several feet of Glacial sand beneath Boulder Clay, in an old small pit (now a plantation) a short distance to the N.E. In this pit the Boulder Clay was from 6 to 8 feet thick.

Hemesby.—In the railway-cutting north of the church, described on p. 31, the Boulder Clay is shown to be much intermixed with a stiff reddish-brown stony loam, which masks a great quantity of the Boulder Clay in this neighbourhood.

The railway-cutting south of the church is described on p. 40.

At a large clay-pit three eighths of a mile S. of Hemesby Hall, 14 feet of Boulder Clay is shown overlying buff and brown Glacial sand.

* Horizontal Section, Sheet 128.

Ormesby St. Margaret's.—In the middle of a field, about a mile E. of the church and on the southern side of the road, is a pit having trees on the western side. Here dark-grey Boulder Clay, 15 feet in thickness, was exposed, overlying 6 feet or more of buff loamy sand, partly hardened at the junction. Many well-striated boulders were observed in the clay; amongst others some of Lias Limestone and Lias Shale, containing numerous fossils. The Boulder Clay is here on comparatively low ground, whereas Lower Glacial Loam occupies high ground in the neighbourhood of California, a short distance off.

Boulder Clay is exposed in the cliff, by the side of the road leading down to the beach at Scratby. It is yellowish-white in the upper part, and grey and black in the lower; contains much chalk; is about 30 feet or more thick; and rests on an undulating surface of mottled grey and brown loam (Lower Glacial), patches of sand sometimes intervening. The section of loam observed was only 12 yards in length, as the cliffs, for the most part about here, are covered with blown sand and overgrown with Marram grass.

During the excavation of the clay, for the Yarmouth Waterworks, from a pit a little more than a quarter of a mile S. of Ormesby St. Margaret's Church, on the eastern side of the road, the following section was exposed:—

	FEET.
Mottled red, grey, and brown sand and loam	4 to 6
Boulder Clay, dark-grey, particularly in the lower part; with many striated boulders, some $1\frac{1}{2}$ feet in length	12 to 15
Sand	?

The following is a list of derived fossils that were extracted from the Boulder Clay. They were got from a labourer, who collected them whilst engaged in excavating the clay. Some were found loose in the clayey matrix, whilst others occurred in the boulders. The specimens are now in the Museum of Practical Geology, where they were identified by MESSRS. G. SHARMAN and E. T. NEWTON:—

Cretaceous.

Brachiolites, and *Lima spinosa*, Sow.

Oolitic.

Serpula tetragona, Sow.
Vermilia sulcata, Sow.
Terebratulina ovoides, Sow.
Corbula sp.
Modiola sp.
Myacites recurva, Phil.
Pecten lens, Sow.
Plicatula.
Thracia depressa, Sow.
Aporrhais sp.

Cerithium sp.
Ammonites alternans, von Buch.
 „ *biplex*, Sow.
 „ *Koenigi*, Sow.
 „ *Lamberti*, Sow.
 „ *rotundus*, Sow.
 „ *triplicatus*, Sow.
Belemnites abbreviatus, Miller.
Nautilus hexagonus, Sow.

Liassic.

Rhynchonella tetrahedra, Sow.
Gryphaea incurva, Sow.
Leda ovum, Sow.

Lima gigantea, Sow.
Ammonites communis, Sow.

Carboniferous Limestone (chert), with *Crinoid* fragments.

Amber, Wood, and vertebra of *Ichthyosaurus*.

On the coast at California a small patch of Boulder Clay overlies brown, more or less indurated and ferruginous, Loam, underlain by sand.

In a clay-pit a quarter of a mile N.E. of Ormesby St. Margaret's Church 15 feet of grey Boulder Clay, weathered to a yellowish-white in places, was exposed, over buff sand. Other clay-pits occur close by on either side.

Ormesby St. Michael's.—A clay-pit three eighths of a mile S.E. of the church was much overgrown when visited by me, but about 8 or 9 feet of

Boulder Clay was exposed, overlying sand. Some indurated pebbly sandstone, more or less of a conglomeratic character, and 9 inches in thickness, was shown at the junction.

A section east of the church has been described on p. 40.

Filby.—Five eighths of a mile N.E. of the church, in a large old clay-pit, from 18 to 20 feet of Boulder Clay was exposed, overlying buff sand, which latter had been excavated to a depth of 6 feet, and contained fragments of shells (*Cardium*, *Tellina balthica*, *Turritella*). The Boulder Clay was bluish-grey, almost black in places, and weathered to a yellowish-white. Several striated boulders were seen in it, the largest being about $1\frac{1}{2}$ feet in length. There was a little brown loam and sand, in places 2 or 3 feet thick, overlying the Boulder Clay; and in the upper part of the latter there was some chalky gravel.

Boulder Clay was exposed in a small pit three eighths of a mile N.N.E. of Filby Church. It is now a pond, with brushwood on the eastern side.

At another small clay-pit, in a field nearly half a mile N. of Filby Church, from 6 to 8 feet of Boulder Clay was exposed, over buff sand.

In a pit three eighths of a mile S. of the church, 15 feet in thickness of Boulder Clay was shown, overlying buff sand.

There is a small clay-pit half a mile S. of the church, where about 6 feet in thickness of Boulder Clay was shown, overlying brown sand.

Thrigby.—In an old clay-pit (now a plantation), a little more than five eighths of a mile S. of Filby Church, east of the windmill, Boulder Clay was exposed, overlying Glacial sand.

Runham.—In a pit a little more than half a mile W.S.W. of the church, grey Boulder Clay had been excavated to a depth of about 13 or 14 feet, and apparently not bottomed. It contained numerous flint, chalk, and other boulders, one being a hard grit. From about a foot to 3 feet of reddish-brown sand and loam overlaid the clay in places.

Mautby.—In a large clay-pit (now much filled-in and overgrown with brushwood, &c.), half a mile S.E. of Filby Church, the Boulder Clay is about 15 feet in thickness, and overlies Glacial sand, which latter is of considerable thickness.

East Caister.—In a pit a little more than three eighths of a mile W. of the church, on the northern side of the road, from 12 to 15 feet in thickness of grey Boulder Clay was shown, overlying brown Glacial sand.

Three other clay-pits in close proximity, about a quarter of a mile N.W. of the church, are now mostly filled-in, and their sections obscured.

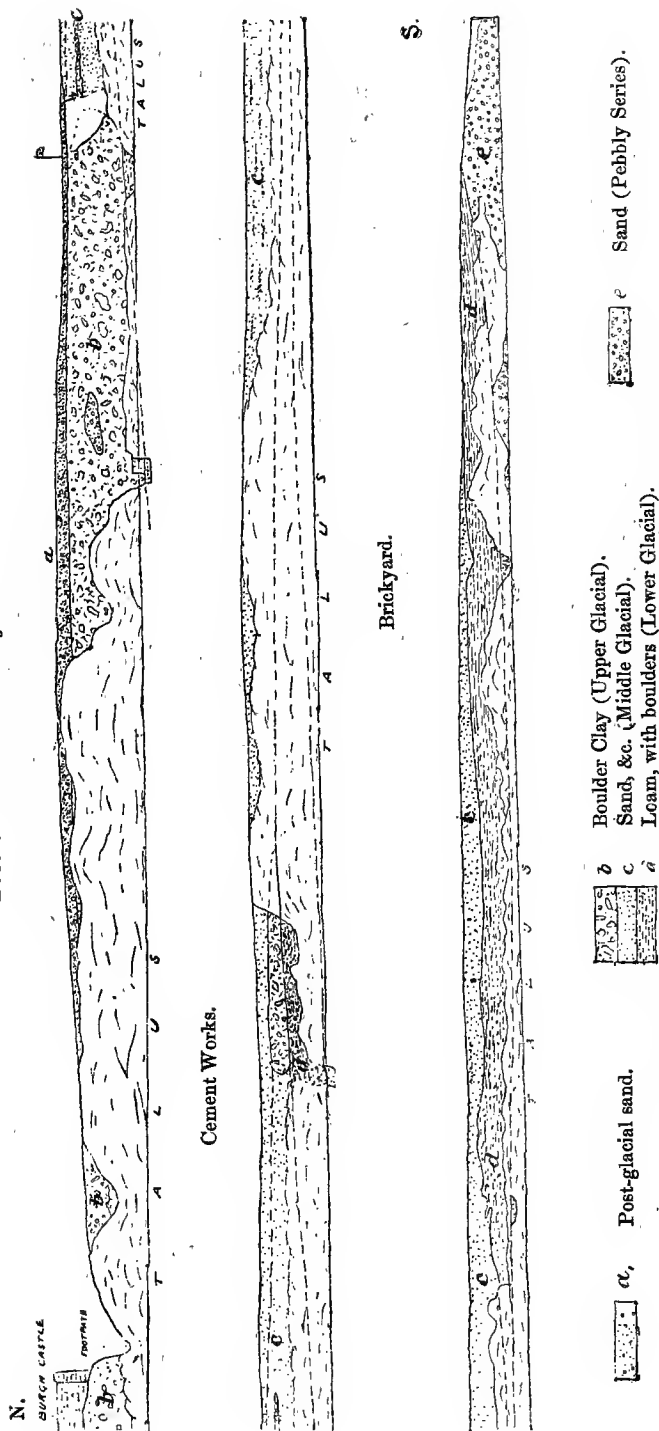
From a pit three eighths of a mile E. of Nova Scotia Farm, and three quarters of a mile N.N.W. of East Caister Church, a large quantity of clay has been excavated. The pit, when visited by me, had been, to a large extent, filled-in; but Boulder Clay was exposed to a depth of 8 feet, and varied from yellowish-white to grey.

Another section at East Caister is described on p. 42, and one at West Caister at p. 41.

Local Details. South of Yarmouth and around Lowestoft.

Burgh (Castle).—At the Cement Works, south of Burgh Castle, a section about 50 yards in length showed 20 feet in thickness of Boulder Clay, resting on brown stony loam, without the intervention of any sand. The clay was dark grey, almost black in places, and contained numerous boulders; one, a much striated septarian nodule, measuring 5 feet in length. The base of the Boulder Clay throughout was very low, being, for the most part, at about the same level as that of the adjoining marshland. It seemed to form a synclinal curve; where the section was, being the lowest portion, and containing the greatest thickness of Boulder Clay. Northwards, between the church and Burgh Castle, several small sections along the face of the escarpment

FIG. 3. Section at Burgh Castle.



The broken lines show the probable continuation of the beds where hidden by talus.
Vertical scale, 60 feet to an inch. Horizontal scale, one mile to five feet.

showed sand between the Boulder Clay and the Loam. Southwards, the base of the Boulder Clay rose at an angle of about $2\frac{1}{2}$ degrees, and in about 110 yards came to within 4 feet of the surface of the ground, where it was overlaid with that amount of sand: the whole mass gradually attenuating and dying out at this spot. When I visited the brickyard adjoining the Cement Works, much of the Boulder Clay at the thickest part of the wedge-shaped mass had been excavated, and merely the thin edge of the wedge left. This was about 30 yards long, and 6 feet thick at the most. It rested on stony loam 15 feet thick, which was underlain by sand (Pebble Series). Eastward, the side of this wedged-shaped mass of Boulder Clay was curved, and presented the appearance of having been jammed against the Glacial sands, which are much disturbed and contorted close to the Boulder Clay. The top part of this latter was much piped, in places where it was overlain with sand, which filled cavities in it.

Fritton.—The section in a triangular-shaped pit, half a mile W. of the church, showed a mass of brown loam of considerable thickness, very irregularly overlying about 5 feet of Boulder Clay; beneath which, at the base of the pit, was sand. The loam appeared mostly to be weathered Boulder Clay, containing pieces of chalk, &c., and went up to the surface of the ground in places; but, in other parts, was overlain by sand and gravel, variously intermixed with loam. A small limestone-boulder, containing *Serpula*, *Belemnites*, &c., was observed in the clay.

Somerleyton.—In a pit, now a plantation, close to and south-west of the church, about 8 or 9 feet in thickness of grey Boulder Clay overlies brown loamy Glacial sand.

At the excavation made for the gas-holder in the grounds of Somerleyton Hall, 12 feet of bluish-grey Boulder Clay overlaid 5 feet of sand.

Chalky Boulder Clay, intermixed with brown loam, was exposed in an old pit, now overgrown with trees, brushwood, &c. S. of East Grove Farm.

Another section at Somerleyton is described on p. 33.

Hopton.—Grey Boulder Clay, overlying Glacial sand, is exposed in several old pits, now mostly overgrown, about half a mile S. of the church. A considerable quantity of clay has been excavated here, and the surface of the ground is loamy.

Corton.—Three patches of dark grey Boulder Clay, overlaid by gravel and sand (Plateau Gravel), were observed in the cliff northward of the village of Hopton, and eastward of Warren Farm. Fresh sections of these patches were constantly being exhibited in this cliff (which mostly consists of Glacial sand) as it was worn back by the combined action of the wind and of the sea, and these were carefully noted during my residence in the district. This was necessary, as at times they looked as if they were lenticular patches of Boulder Clay in the Glacial sands; but, after repeated observations, I was convinced they were all introduced after the deposition of those sands, and are therefore posterior in age to them. These observations were instructive, and suggestive of the necessity of caution in the interpretation of sections, even when so well exposed as in a sea-cliff; for, on several occasions, the sections of these patches of Boulder Clay were in favour of conclusions which were afterwards shown to be erroneous.

A pit-section W.S.W. of Corton Church is described on p. 43.

Lowestoft.—The Boulder Clay at the brickyard, described on p. 44, was used for the manufacture of bricks, which when burnt were of a yellowish-white colour, sometimes mottled with a little red or pink.

At the clay-pit, a little more than three eighths of a mile S. of St. Margaret's Church, and on the northern side of the footpath, the following section was exposed:—

		FEET.
Glacial Drift	Reddish-brown loam, containing irregular patches of Boulder Clay, and some irregular patches of marl at the base -	3
	Bluish-grey Boulder Clay, with many chalk and flint boulders, and a few of other rocks, several a foot long, and much scratched -	7-10
	Very fine buff sand, well stratified -	2

A large boulder of Lias Shale projected in a conspicuous manner from the clay; and also a much rounded one of gritty sandstone.

Oulton.—At the brickyard half a mile W. by S. of St. Margaret's Church, Lowestoft, on the southern side of the road, the following section was exposed:—

	FEET.
Plateau Gravel. Brown sand, loam, and clay, stratified in places	6 to 8
Glacial Drift { Boulder Clay, dark grey, almost black in places	20
{ Buff sand	20

In the adjoining brickyard, the Boulder Clay is of the same thickness and colour; and also underlain by 20 feet of Glacial sand, at which depth water occurs. Red and whitish bricks are made in both yards, the Boulder Clay making the whitish bricks.

Descriptions of two other sections at Oulton will be found on p. 33.

Burgh St. Peter.—In a pit to the west of that E.S.E. of Wheatacre Church (see p. 46), on the other side of the road, Boulder Clay was shown overlying Glacial sand; but the pit was too much overgrown to see the thickness of the beds.

The following section was exposed in a pit a little more than $1\frac{1}{2}$ miles S.E. of Wheatacre Church, on the western side of the road, close to Seven-mile Car:—

Glacial Drift {	Boulder Clay, 9 to 10 feet.
	Gravel and sand, 4 feet.

At a pit half a mile S.W. by W. of Burgh St. Peter's Church, the following section was exposed:—

Glacial Drift {	Dark grey Boulder Clay, 10 to 3 feet.
	Sand, clean, stratified, buff and whitish, with many grains of chalk, 6 to 13 feet.

The Boulder Clay rested unconformably, and in an undulatory manner, on the sand in the following way: the surface of the ground, and the floor of the pit, were respectively about the same level at both ends of the section; yet, at one end, 3 feet of Boulder Clay overlaid 13 feet of horizontally stratified sand; whereas, at the other end, only 30 feet from it, the Boulder Clay so wrapped over the sand, that 10 feet of the former overlaid only 6 feet of the latter, about 7 feet having apparently been eroded at this end; before, or during, the deposition of the Boulder Clay. A somewhat similar wrapping over of the Boulder Clay was well exposed in a pit a quarter of a mile W.S.W. of Rollesby Church, where the greatest thickness of the clay occurred on the sloping ground (see p. 40), and the same phenomenon has been seen elsewhere.

Another section at Burgh St. Peter is described on p. 46.

Wheatacre.—At a pit in the field immediately south of Mouser Farm, nearly three quarters of a mile N. of the church, about 10 feet of grey Boulder Clay, very marly in places, was exposed, overlaid with a little Plateau gravel and loam. Glacial sand was exposed on the southern side, which was much grown over, so that the relation of the beds was not well shown.

A section S.E. of the church is described on p. 46.

Carlton Colville.—Tiles and pipes are made with the clay, as well as red and white bricks, at the brickyard described on p. 46, and another section is described on that page.

Aldeby.—The clay is exposed at the sides of the pond, close to the farm-buildings, a few yards east of the railway-station.

About 9 feet in thickness of Boulder Clay was exposed in a pit $1\frac{1}{2}$ mile S.E. of Wheatacre Church, on the western side of the road, north of some farm-buildings, and close to the Marshes.

A clay-pit occurs a little more than a mile S. of Wheatacre Church, on the southern side of the road. From 12 to 14 feet in thickness of grey Boulder Clay was exposed, with white marly patches. A Lias limestone-boulder, containing a large Ammonite, projected from the clay, the portion exposed measuring $2 \times 1\frac{1}{2}$ feet.

Other sections at Aldeby are noticed on p. 45.*

Sections at Blundeston, Ellough, Gisleham, Gorleston, Gunton, Kessingland, Lound, Mutford, and Rushmere are described on pp. 42-44, 47, 48.

* See also *Geology of the Country around Norwich (Mem. Geol. Survey)*, pp. 86, 141.

CHAPTER VIII. PLATEAU GRAVEL.

GENERAL REMARKS.

This deposit, which mostly consists of unstratified coarse flint-gravel, but in places contains loam and sand, occupies some of the highest ground in this district, as it does elsewhere; and for the most part was accumulated under conditions which were independent of the present drainage-system. It overlies, and is unconformable to, the Boulder Clay, and appears to have been accumulated just after or during the break-up of the glacial conditions that prevailed during the time of the formation of the Boulder Clay.

On reference to Sheet 67, S. of the Geological Survey Map, it will be seen that irregular patches of it occur here and there south of Yarmouth and around Lowestoft. The largest patch in the district, north of Lowestoft, measures $2\frac{3}{4}$ miles in length along the face of the cliff, and in places is 23 feet or more in thickness. It occurs here in a plateau-like form, and its surface, in the neighbourhood of St. Margaret's Church, Lowestoft, is 97 feet above the mean sea-level, and at Corten 74 feet.

It is interesting to observe how the geological mapping of the ground clearly proves that the valley at Gunton has been cut out since the deposition of this Plateau Gravel, and that the upper end of this valley must have originally been considerably to the eastward, in a position now occupied by the North Sea. And what is thus apparently demonstrated to be the period of excavation of this valley, would also, judging from the position of the Plateau Gravel, be the period of excavation of others in the district. The incipient stage of this valley-erosion would seem to have taken place immediately after or during the emergence of the Drift deposits from beneath the sea.

The stones composing this gravel are sometimes much rounded, and at other times almost entirely subangular, and very much resemble those of Valley Gravel; and although they mostly consist of flint (some 8 inches long and larger), others of various rocks are in places sometimes intermixed, as will be seen from the details of some of the pit-sections.

The deposit, so far as ascertained, is entirely unfossiliferous.

Further information respecting it has been given in the Memoir on "The Geology of the Country around East Dereham," in which district large masses of it occur.

[It should be understood that the use of the term Plateau Gravel here is meant to be purely local, and not to imply that the deposit is of the same age as gravels that form plateaux at higher levels elsewhere. Such questions are for a general Memoir rather than for one of a local and limited character.—W.W.]

LOCAL DETAILS.

Burgh (Castle).—A patch of brown and buff sand, gravelly in places, overlies the Boulder Clay a short distance south of Burgh Castle. At the section near the Cement Works it varied from 3 to 6 feet in thickness. The section (fig. 3, p. 55) shows the relation of the various deposits here, the detailed descriptions of the beds above the Pebbly Series being given on pp. 32, 42, 54-56.

Fritton.—Gravel, sand, and loam, variously intermixed, overlie Boulder Clay in places west of Fritton Decoy, as shown in a pit half a mile W. of the church.

The outlier of Boulder Clay N. of Fritton Church is mostly covered with a sandy deposit, which is so thin and lies so irregularly that it was ignored in mapping. It is evidently, however, of the same age as the patch of gravel, sand, and loam that has been mapped on the high ground south of the Broad or Decoy.

Ashby.—A gravel-pit occurs three eighths of a mile W.N.W. of Somerleyton Hall, on the northern side of the road. About 6 feet in thickness of coarse, reddish-brown, flint-gravel was exposed, with one or two patches of sand in it, on the whole very similar in appearance to Valley Gravel. Several of the flints measured from 4 to 8 inches in length, and were more or less subangular, though some appeared to have been much water-worn.

Hopton.—At about a mile north of the church, four small patches of Plateau Gravel occur around Warren Farm, partly in the parish of Hopton and partly in that of Corton. They all rest apparently on Glacial sand, with the exception of one which is shown in section in the cliff to be partly underlain by a lenticular patch of Boulder Clay, 130 feet in length and 6 feet in thickness in the central portion, the overlying gravel being 12 feet thick, and consisting mostly of unstratified coarse flint-gravel; but there was some sand in places intermixed, which was well stratified and contained some loamy and ferruginous bands. Although, at times, the section of this gravel presented the appearance of being interstratified with the Glacial sand, yet after carefully examining fresh exposures of the section, as the cliff was worn back, I was satisfied that there was a plane of unconformity between the Plateau and Glacial sands and gravels, which plane passed under the Boulder Clay and came up to the surface of the ground, or to the top part of the cliff, $2\frac{1}{2}$ chains to the south, and $3\frac{1}{2}$ chains to the north of the extremities of the patch of Boulder Clay.

Corton and Gunton.—In the ornamental grounds around the residence of Mr. J. J. Colman, M.P., at Corton, sand and gravel occur overlying the Boulder Clay, and according to the head-gardener, averaged from 5 to 10 feet in thickness.

Gravel, sand, and loam, variously intermixed, overlie the Boulder Clay on the highest ground in the neighbourhood of Gunton, good sections being exposed in pits on both sides of the road to Corton, about half a mile N.N.E. of Gunton Church. The following section was exposed in the pit on the eastern side of the road, adjoining the brickyard:—

	FEET.
Plateau Gravel, &c. { Coarse, light-coloured, flint-gravel and sand, roughly stratified in places. The gravel contains many flint pebbles, together with a few of quartz, and in places is of a shingly nature - - - -	12
	Brown loam, rather sandy - - - - 8
	Bluish-grey loam - - - - 3
Glacial Drift. Boulder Clay - - - -	6 +

In a pit an eighth of a mile N. of Gunton Hall, 6 feet of gravel, with a little sand and loam in places, was shown overlying Boulder Clay. The gravel is of the nature of shingle in places, and mostly consists of pebbles of flint with a few of quartz, together with a few small boulders of granite, grit, flint, quartzite, &c., some 9 inches in diameter.

Lowestoft.—At one of the brickyards five eighths of a mile W.S.W. of St. Margaret's Church, on the western side of the road, the following section occurred:—

			FEET.
Plateau Gravel, &c.	{	Coarse flint-gravel, irregularly overlying red sand and sandy loam	9
		Laminated brown and yellow loam	2
		Laminated dark grey loam	2½
		Laminated black loam	¼
		Brown silt and gravel	½
		Laminated black and white strong loam, in alternating seams	1 to 3
Glacial Drift	{	Boulder Clay-	13
		Buff and white sand, proved in well (see p. 83)	to 30

The laminated loam above the Boulder Clay is of sufficiently good quality to make drain-pipes, chimney-pots, &c.

Another Lowestoft section has been described on p. 44.

Oulton.—The section in a pit half a mile S. of Flixton Church, on the eastern side of the angle in the road, showed 10 feet of brown gravel, consisting almost entirely of small flint pebbles, from 1 to 2 inches in diameter, with some from 3 to 4 inches, and also some small boulders of hard grit, of quartz, and of other rocks, sparsely scattered.

Wheatacre.—The surface of the loamy land in the immediate vicinity of the Board School, where there is a well (see p. 81), is very springy, owing to the water being kept up by the more or less impermeable Boulder Clay.

Aldeby.—Gravel is to be seen overlying sand in pits on the sloping ground between the railway and Aldeby Hall. In a pit S.E. of the Hall 12 feet in thickness of gravel was exposed, sand being shown in a pit at a lower level. Gravel has been excavated for ballast for the permanent way in pits close to the railway.

Burgh St. Peter.—At a short distance from the pit described on p. 46, there is another gravel-pit, five eighths of a mile S.W. by W. of the church, where the small outlier of Plateau Gravel is shown on the Geological Survey Map. The gravel exposed, resembled shingle in appearance, and, as in the above pit, inclined southwards at a very considerable angle (probably more than 30°) towards the Marshes.

CHAPTER IX. RECENT DEPOSITS.

ALLUVIUM.

General Remarks.

A period of time, sufficient for the excavation of the valleys in this eastern part of England, would appear to have elapsed between the deposition of the Plateau Gravel and the commencement of the deposition of the alluvial formations now to be described. These latter occupy, or fill up to sea-level and above, the lower portions of those channels or valleys which have been eroded through the Drift and Pliocene beds.

The difference of level between the Plateau Gravel and the Alluvium, which in places in this district are in comparatively close contiguity, is remarkable. The Plateau Gravel in the neighbourhood of Lowestoft occurs at a height of 97 feet above Ordnance Datum, whilst the lowest portion of the alluvial deposits at Yarmouth is at a depth of 150 feet beneath the same level, a vertical difference of 247 feet.

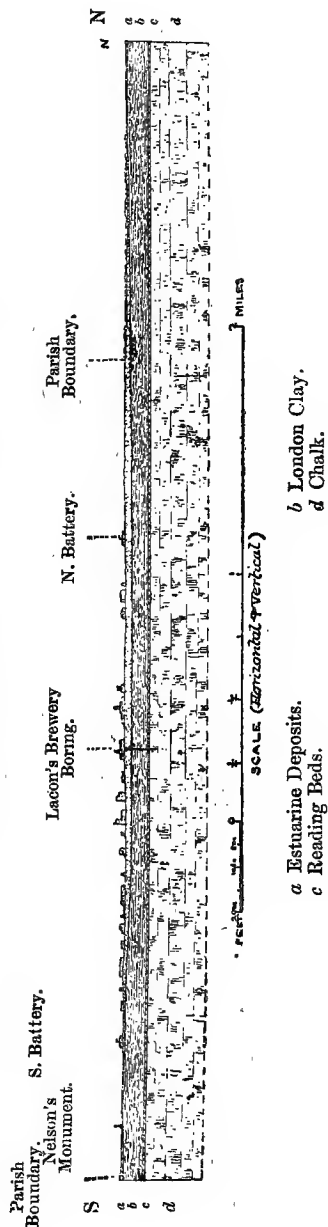
It was apparently at the close of the Glacial period, therefore, that the present configuration of the land relatively to the sea was, for the most part, brought about, and the present drainage-system established: with the exception of such modifications (some not inconsiderable, others almost nil), that have since taken place, principally, if not entirely, in this district by atmospheric and aqueous agency, similar to what has taken place in recent times, and is going on at the present day.

It is obvious, as well as authenticated by historical facts, that when the present drainage-system was established, this portion of East Anglia must have extended considerably further to the eastward, where the North Sea now is. And it is the destruction and removal of this portion of England that is particularly alluded to, when mentioning that some of the modifications of the configuration of the land that have taken place since the Drift period, and in recent times, has not been inconsiderable.

Moreover it is the débris of this coast-destruction that has, to a very large extent, assisted to silt-up the Yarmouth estuary, conjointly with the débris brought down by the rivers. This silting-up process no doubt increased at a rapid rate with the growth of the bar that contracted the mouth of the estuary, and which eventually not only formed across it, but continued its progress for several miles southward to beyond Corton, and thereby turned the river Yare that amount to the south before it could find an outlet to the sea (*see* p. 68).

It was thus, apparently, that the deposits were accumulated which form the extensive tract of Alluvium shown on the map. And it is the surface of this alluvial flat or marshland, dotted with innumerable wind-mills for drainage-purposes, that constitutes such a distinguishing and marked feature in this district.

FIG. 4.
Section showing the Hollow of Estuarine Deposits at Yarmouth.



Marine and estuarine deposits contributed mostly towards the formation of the alluvial formation in the neighbourhood of Yarmouth, and for a considerable distance inland; whilst fluvial and lacustrine deposits formed in the upper portions of the valleys.

Details respecting this great mass of estuarine deposits that occurs beneath Yarmouth are given in the account of the deep well-boring (p. 81), and PROF. PRESTWICH, in the description he has given of it, makes the following observations:—

“Beneath the [Blown] sand and shingle we have the opportunity (rarely offered) of tracing a complete section of a very recent estuarine deposit. It consists of 120 feet of tranquilly deposited sand and silt in alternating beds. Unfortunately, the shells being in such a fragmentary state, few species can be determined. I have been aided in these by Mr. Rose, of Yarmouth, who has carefully gone through all the specimens again, and made the necessary comparisons. A considerable portion of the fragments have evidently been washed out of the adjacent Crag, which at that time probably extended in exposed banks on either side of the old river-estuary. I do not, however, believe that any portion of the 120 feet belongs to the Crag itself; there is too much uniformity throughout the mass, and it is too argillaceous. The level of the adjacent Crag is higher; and there is no reason to suspect a depression in the London Clay anterior to the Crag-period coincident with the depression in the recent surface, or in the Chalk; and all the fragments are of such shells as might be washed out of the Crag, or are living as well as Crag species.”*

The base of this 120 feet of estuarine deposits, which rests in an excavated hollow in the London Clay, is 150 feet beneath the mean sea-level. The additional 30 feet at the top at the site of the boring, being, according to PROF. PRESTWICH, beach-sand and shingle. Possibly a little further westward this 30 feet may be represented by estuarine deposits, thus making the total thickness of the alluvial accumulation 150 feet.

“From the earliest period,” says MR. R. C. TAYLOR, “there evidently existed a tendency to deposit oozy matter in the valleys, which tendency was materially increased, when, by the subsequent operations of nature, the outlets against the sea were narrowed. . . . This tendency of turbid waters, when in a state of comparative quiescence, to deposit the substances they hold suspended, is converted to the benefit of the landowner in abundance of instances; some of them even on the coast of Norfolk; and, in the words of one of the parties, has proved a mine of wealth to those who have availed themselves of it. . . .”

“In proportion as the entrance for the tidal waters was gradually restricted, and their escape was impeded, did the æstuary of the Yare remarkably resemble one of those large artificial enclosures which are embanked for the purpose of warping. Had an engineer, in remote times, projected the conversion of this once extensive waste of waters into a tract of valuable land, as it now exists, his principal operations would assimilate to those which Nature by degrees performed without his intervention. Were those natural barriers which have interrupted the entry of the great body of water, removed; were our estuaries again emptied of the ooze and alluvium which have filled them,—the same circumstances, making reasonable allowances for the interposition of man, would be renewed; the waters would again flow up to the walls of Norwich, as high and as freely as they ever did; the same system of obstruction and silting would re-commence, and finally would re-conduct to the same phenomena as are at the present moment exhibited. . . .”

“None of the marshes, at the points where the salinæ mentioned in Domesday [Book] are conceived to have been situated [see p. 77], are elevated so much above the level of the sea as to be inapplicable to their original

* *Quart. Journ. Geol. Soc.*, vol. xvi. p. 451. Mr. S. V. WOOD, JUNR., thought that some of the Cromer beds might be represented, rather than recent estuarine beds (*Geol. Mag.*, vol. iv., p. 560).

purposes, were not the mouths of the æstuary, as I endeavoured to explain, filled up so as to exclude an adequate supply of salt water.* The levels, recently taken by various engineers, prove that the rivers in their progress thence to the ocean have little or no fall: it is well known the marshes for many miles from the sea are below the levels of those rivers; and in the evidence on this subject before the committee of the House of Commons, it was deposited, that on the occasion of the sea breaking through Lake Lothing, 35 years before, it covered this entire level of marshes to the depth of 3 to 3½ feet with salt water."†

Local Details. North of Yarmouth.

Horsey.—The trunk of oak found in the well here (see p. 80) laid horizontally across the well, in such a manner that it had to be sawn through on either side before further excavation of the well could be proceeded with.

Hickling.—I was informed by an intelligent man in charge of Eastfield Mill, nearly 1½ miles W. by N. of Horsey Church, that there were 2,000 acres of land to drain in that neighbourhood, and that the water was sent into the Hundred Stream, and from that into the River Bure, and so to the outlet into the sea at Gorleston. The marshes in the neighbourhood, he stated, consisted of "moor" and "ooze," in which deers' horns and various bones had been found; also trunks of trees, &c. (oak, ash, poplar, larch, alder, willow, &c.); and, in places, where the alluvium was of an "oozy" nature, shells had been found.

The above statements were corroborated from information obtained from other sources, and, to a large extent, by my own observations.

Potter Heigham.—In excavations and borings made in the marshland, in the spring of 1879, in connection with the foundations for the iron-girder railway-bridge across the Hundred Stream, about 100 yards N.E. of the road-bridge, and seven eighths of a mile S. of Potter Heigham Church, the following section was observed:—

	FEET.
Alluvial and Estuarine Deposits, about 58 feet	
Bluish-grey loam, clay and "ooze," blackish in places, micaceous, and containing a few thin seams of sand	24
Grey silty sand	½ to 2
Stiff bluish-grey loam, clay, and silt	13
Black peat, hard, and apparently very much compressed	17
White and buff sand	2

The bed of loam, clay, &c. above the peat was more or less saturated with water, and contained cockles (*Cardium edule*) and other shells in various places, many with their valves united. They were abundant just above the peat; and some by me whilst I write, look almost as modern as those to be seen on the sea-shore. Some pieces of wood and other vegetable matter were met with here and there in the micaceous grey loam; one piece, which I have, is of the same grey colour as the loam, has been rounded like a pebble, and measures $2\frac{1}{2} \times 1\frac{1}{2}$ inches. The knowledge of the thickness of the peat (17 feet) was obtained by a boring; and when the great thickness was ascertained, it was decided by the engineers to utilize the peat for the foundations of their bridge, by sinking iron-cylinders (6 feet in diameter) to the surface of the same, that is, to a depth of about 39 feet beneath the level of the marsh-land.

Martham.—A brickyard is situated on the Marshes, south of the Hundred Stream, by the Swim and Staithe, about three quarters of a mile N.W. of the

* "It is not essential to a saltwork that any considerable depth of sea-water should be within command; the quantity required is uniform, but not large: I believe about 10 inches deep in the reservoirs, and $1\frac{1}{2}$ to 3 inches only in the pans."

† *Phil. Mag.*, ser. 2, vol. ii., pp. 300-302, and reprinted in his "Geology of East Norfolk," pp. 56-59, 1827.

church. An excavation had been made close to the bank of the Hundred Stream, and continued about 80 yards southwards. At the northern end, by the Hundred Stream, when the excavation had been carried to a depth of 16 feet, an old land-surface was met with, consisting of turf and moor, resting on sand in some places, and on hard "pan" and gravel in others. Stools of trees occurred here in place, with prostrate trunks of trees above them. I was informed that, at 2 feet above the turf of the land-surface, a shelly band 8 inches in thickness was met with, containing shells of cockles and mussels. The old land-surface had been traced southwards to a distance of about 80 feet, at which spot it was found at 8 feet beneath the present surface of the marshland. The alluvium had been excavated for the manufacture of bricks, and consisted mostly of a black loamy "ooze" or silt, which when burnt made a light mottled reddish brick, but not of good quality. This old land-surface at the base of the alluvium is in all probability of the same age, as that $5\frac{1}{2}$ miles further north on the coast at Palling (the marshland being continuous throughout that distance), and which has for many years been erroneously described by various authors as a portion of the so-called Pre-glacial Forest-bed. On one occasion, after a scour of the beach, I was fortunate in seeing a remarkably fine exposure of this comparatively recent forest-bed; it extended north-westward along the sea-shore for about half a mile, from near the Cart Gap at Palling to a spot about three quarters of a mile S. of the tower, which alone remains, of Eccles Church. Numerous blackish stools of trees, with their rootlets attached, unquestionably in place, and in a comparatively good state of preservation, were observed along this portion of the coast.

Local Details. South of Yarmouth and around Lowestoft.

Burgh St. Peter.—In excavations made in the marshland a short distance south of the church, for improving some of the dykes and their banks, a large quantity of fresh-water and estuarine shells, &c., were dug up. I obtained specimens of the following species:—

Bythinia tentaculata, Linn.

Helix arbustorum? Linn.

Limnaea palustris, Drap.

„ *peregra*, Drap.

Planorbis complanatus, Linn.

Cardium edule, Linn.

Scrobicularia plana, Da Costa (= *piperata*, Linn.)

BEACH-SAND AND SHINGLE.

The beach along the coast of this district mostly consists of fine buff sand, with a little shingle, mostly consisting of flints, at tide-marks; but here and there, as in front of the village of Pakefield, there is a considerable accumulation of shingle for a short distance.

These shore-deposits, where they occur in front of the cliffs, are for the most part of no great thickness; this is shown, occasionally, when they are in places entirely scoured out by the sea, and the underlying Pliocene or Glacial beds are exposed to view. In the neighbourhood of Yarmouth and Lowestoft, however, they are probably of much greater thickness.

The materials that form the beach along this coast travel southwards; consequently, when groins or breakwaters are constructed at right angles to the cliffs or coast-line, the sand and shingle accumulate on the northern side, as is well exhibited at Gorleston and at Lowestoft. It is due, apparently, to the tidal current, which flows with a much greater velocity towards the south than it ebbs towards the north.

"In the North Sea the flood tide-wave enters from the Atlantic Ocean between the coast of Norway and the British Isles, and passes through the various channels formed by the Shetlands, the Orkneys, and the north point of Scotland." The stream "swells along the shores of Scotland and England, and makes high water in all their rivers and harbours successively till it arrives in the Thames."

"Near the Norfolk and Suffolk coasts the streams of tide run nearly parallel to the shore."

"At $2\frac{1}{2}$ miles off Lowestoft the flood stream continues to run to the S.S.W. till 1 h. 30 m. before high water at Harwich."

"The direction of strong winds, as well as the varying pressure of the atmosphere, considerably affect both the times and the heights of high water. Thus in the North Sea a strong N.N.W. gale and a low barometer raise the surface 2 or 3 feet higher, and cause the tide to flow all along the coast from the Pentland Firth to London half an hour longer than the times and heights predicted in the Tables. Easterly, S.E., and S.W. winds produce opposite effects." *

Time of High Water on Full and Change Days, arranged according to the apparent progress of the Tide Wave. With the Rise of the Tide at Springs and Neaps.†

Place.	High Water, Full and Change.	Rise.	
		Springs.	Neaps.
Winterton Ness - -	H. M. 8 25	FT. $7\frac{3}{4}$	FT. $6\frac{1}{4}$
Yarmouth Road - -	9 15	6	$4\frac{1}{2}$
„ Haven, Brush -	—	$5\frac{3}{4}$	$4\frac{1}{4}$
„ Bridge -	—	5	4
Lowestoft ‡ - -	9 57	$6\frac{1}{2}$	$5\frac{1}{4}$

The range of tide gradually decreases around the coast from Lynn, where the rise at Springs is 23 feet, until at Yarmouth it is only 6 feet; it then gradually increases, being $6\frac{1}{2}$ feet at Lowestoft, until at Margate it is $15\frac{1}{2}$ feet.

"In their progress the tidal currents possess sufficient strength and velocity to preserve a deep channel, locally called "Roads," parallel with the shore; but they deposit, both on the sea and land sides of this passage, the alluvial matter with which the waters are charged. Mr. Cubit has appropriately denominated this channel a sea-river. A portion only of the substances that form the shoals and sand-banks may be considered shifting, and these are modified by every variation of wind and tide. The nuclei of most of the largest appear to be permanent, and probably existed at a period far more

* Admiralty Tide Tables, etc.; for the British and Irish Ports, for the year 1879, pp. 112, 113, and 114.

† "By the Rise of the tide is meant its vertical rise above the mean low water level of spring tides."—Admiralty Tide Tables, etc., p. 153.

‡ "Heavy southerly gales reduce the depth of water 2 or 3 feet below that shown in the Barnard and Pakefield Channels."

remote than we can estimate. Thus the antiquity of the Holm-sand, opposite Lowestoft, is decided by its Anglo-Saxon name.”*

From what has been stated, it will be seen there is a tendency on the part of Nature to form a barrier of beach-materials, travelling from north to south, across all the estuaries, harbours, rivers, or streams that may have their outlet on this eastern coast; and to turn the course of the rivers down southwards. This is exemplified at the present day at Great Yarmouth and Lowestoft, and the river Yare is now diverted a distance of $2\frac{3}{4}$ miles to Gorleston, where it has an artificial outlet, and was previously diverted to a much greater distance further south.

“The most serious evil, which for centuries has embarrassed the navigation and occasioned enormous charges upon the inhabitants of Yarmouth and the trade of this district, is acknowledged to reside in the difficulty of maintaining an open haven, of sufficient depth to enable ships of moderate draught to pass over the bar. From the time of Edward III., when the sea deserted, or rather choked up the ancient northern channel, even to the present day, there have been constant struggles between man and the ocean, to preserve an outlet adapted to the necessities of commerce; and the history of these events evince the unwearied industry and the laudable perseverance of the townspeople. In the course of the first two centuries, seven new havens, in different situations, were successively constructed, at average intervals of about thirty years.”†

The dates of the formation of these havens are as follows ‡:—

				Year.
1st Haven.	The outlet of the river being at this time at Gunton,			
	6 miles from Yarmouth, a new haven was cut at Corton			1347
2nd „	A new haven was cut against the Horse Ferry, N. end of			
	Gorleston	-	-	1392
3rd „	Do.	do.	near Newton Cross	-
				1408
4th „	Do.	do.	nearer the town than the last	-
				1508
5th „	Do.	do.	eastward of the Parsonage at	
	Gorleston	-	-	1528
6th „	Do.	do.	near the South Gate of the town	-
				1549
7th „	Do.	do.	eastward of the Parsonage at	
	Gorleston	-	-	1560

In 1566, a certain Dutchman, Joas Johnson, constructed a North Pier, and in the following year a South Pier, which remain to the present day, with additions and alterations.

It may be of interest to quote the following remarks from Mr. J. B. REDMAN's paper on “The East Coast,”§ as coming between the older works, noticed above, and the time of the Geological Survey:—

“At Lowestoft Ness, the foreshore is mainly sand. The entire upper surface on the south side, in the neighbourhood of the open timber Low Light Tower, is covered with white driven sand, of a flocculent character, shifting rapidly in every direction. . . . An ancient ‘full’ of sand and shingle, parallel to the cliff, is traceable within the angular accretion and projection of the Ness. At the point of the Ness commences a shingle ‘full’ of pebbles, the largest being on the crest. These are collected for building and road purposes, and measure 5 ins. × 3 ins. × 2 ins. Round the north-east elbow

* R. C. Taylor's *Geology of East Norfolk*, p. 32; reprinted from *Phil. Mag.*, ser. 2, vol. i., p. 352 (1827).

† R. C. Taylor's *Geology of East Norfolk*, pp. 45, 46 (1827).

‡ From Manship's *History of Great Yarmouth*; MS. completed 1619.

§ *Proc. Inst. Civ. Eng.*, vol. xxiii., pp. 209-212 (1865).

two 'fulls' of fine shingle make their appearance, and two early 'fulls' inside: then pure sand. . . At the Point the foreshore of sand and shingle is steep . . the navigable channel lying close in . . . There is deep water, 6 fathoms, close to the Ness . . Across the 'Denes,' on the north side, opposite the boat-house, the following is a section of [= across] this remarkable spit":—

"25 yards, sand and shingle foreshore, 7 to 1 [slope];
 6 " 'full' of recent shingle at high water;
 30 " sand and large blue pebbles up to grass-grown sand
 'Denes.'"

"Northward the shingle is less defined. From the sand-hills seaward there is a long foreshore; to a regular slope of sand and pebbles 100 yards in breadth, down to low water. The shingle 'fulls' are local at the point of the Ness."

"There have been considerable fluctuations in the point of the Ness, during the last ten years [before 1864], the general result being, a wasting of the shore on the weather or N.E. side, accompanied by a corresponding local increase on the leeward or S.W. side, producing a southern movement of the Point."

"The sands at Yarmouth, like those at Lowestoft, have been comparatively stationary for the last quarter of a century. They have a per-centage of flint boulders, a large number of which have been used for making roads. . . When it is considered that this area of sand, 5 miles in length . . and half a mile wide, equal to 1600 acres, has been formed across what was a large estuary during the occupation of the country by the Romans, some idea may be formed of the enormous accumulations that have taken place. . . The old town of Yarmouth was formerly on an island, with two outfall channels—one at Caistor, the other at Gorleston. The first was eventually abandoned, and the town consequently decreased on the north side, and extended southward. The Gorleston Channel, which was formerly subject to continual fluctuations, was, after much labour, rendered permanent. . . In the reign of Edward the Confessor the two outfalls were, one between Yarmouth and Caistor, called 'Grub's Haven' and sometimes 'Cockle Water,' and the other 3 miles to 4 miles south of Yarmouth . . and there were six successive havens before the formation of the present outlet in 1559. . . The tendency has always been for the north bar . . to travel south across the entrance."

Owing to the increase of shore-sand in front of the town and at the entrance to the harbour, MR. REDMAN thinks that "the harbour of Yarmouth is now [1865] rapidly lapsing to the condition it was in half a century back, when 10 feet, and not 15 feet, was the maximum depth over the bar."

Of Winterton we are told that there is "beach in the hollows" between the hills of Blown Sand northward to the Ness; and that "at the extreme north-east spit . . off the signal station east of Warren House, the sand-hills diminish in height, and shingle is driven through the interstices . . where reduced by the sea. Northward, the 'full' of large pebbles increases in volume."

In the Second Report of the Committee for inquiring into the Erosion of the Sea-coasts, Major A. G. CLAYTON, R.E., states that the W.N.W. wind is the most important in piling up shingle at Yarmouth, that the shingle does not travel, and that it is apparently diminishing, partly through abstraction for ballast, from between high and low water-mark.*

BLOWN SAND.

Irregular-shaped hills or dunes of Blown Sand border a large portion of the coast, and form a very conspicuous feature in this district. In combination with the Beach Sand and Shingle, and

* *Rep. Brit. Assoc.* 1886, p. 852 (1887).

more or less overgrown with vegetation, they form a natural embankment in front of the alluvial flats or marshes ; which would otherwise be overflowed or “drowned” by the sea ; as they are in many places as much as two, and three feet, and more below the level of high water of spring tides.

These hills of Blown Sand or so-called “Marram* Hills” are well seen between Winterton and Waxham and extending to Eccles, where they average from about 30 to 50 feet in height. Sometimes, as in front of the old sea-cliffs at Winterton, there are two or three, or more, successive embankments or ridges of Blown Sand, more or less parallel with one another. This is also the case in front of the old cliffs at Lowestoft, where in places the Blown Sand forms concentric ridges ; and, in combination with the Beach Sand and Shingle, constitutes the most eastern part of England. This low-level strip of land, known as “the Denes,”† which has been regained, so to speak, from the sea, is about $2\frac{3}{4}$ miles in length, and more than $\frac{2}{3}$ ths of a mile in width at its widest part, Lowestoft Ness.

The strip of land known as “the North and South Denes” in the neighbourhood of Yarmouth, and on a portion of which the town is built, extends from East Caister to Gorleston. The materials of which it consists are Beach Sand and Shingle, more or less covered with Blown Sand. This tongue of land which has been formed across the old estuary, as previously stated, measures now about $5\frac{1}{2}$ miles in length ; and in a somewhat similar manner, as at Lowestoft, has also, so to speak, been regained from the sea, it being more than $\frac{2}{3}$ ths of a mile in width in front of the old sea-cliff at Gorleston. This tongue of comparatively recently formed land, formerly extended to Gunton ; it is now, in consequence of the construction of the pier or breakwater at Gorleston, artificially prevented from extending itself further southward ; as is also the patch at Lowestoft.

The hillocks of Blown Sand decrease in height from East Caister to Great Yarmouth and Gorleston ; and also from Corton to Lowestoft Ness. The sand composing them is partly derived from beds in the cliffs, and partly from the sandy fore-shore : it accumulates very rapidly during windy and especially tempestuous weather ; “dunes” or “denes,” several feet in height, being formed in a few hours.

Sometimes gaps are made by the sea during stormy weather in the natural embankment of Blown Sand between Winterton and Waxham : on these occasions sand is then frequently blown through the hollow inland over the marsh, in such a manner as to form a natural buttress to the embankment, the gap or breach being usually more or less closed up again in a few days. Whilst mapping the district I observed several of these irregular-shaped

* From the Gaelic *Muran*, the Sea Reed, or perhaps from the Dutch *Marren*, to bind ?

† The word “Denes” corresponds with *Dunes*, *Duynen*, used by the French and Flemish for places of the same kind on the opposite coast.—Mumford’s Local Names in Norfolk.

buttresses to the east of Horsey, and have shown them on the Geological Survey Map, two or three being seen in course of formation.

But for this natural barrier of sand-hills, fixed or united by the growth of the "Marram" (*Arundo arenaria*) and other plants, the sea might enter, and spread over 40,000 acres of land, as has been calculated. There are records stating that nine gaps or breaches were made through this embankment in 1792. They were measured by MR. FADEN, who ascertained that together they were 484 yards wide. On this occasion "a body of water passed through between Horsey and Waxham, extending beyond Hickling, a village situated three miles inland, which, uniting with the fresh water contained in a large lake, termed the Hickling Broad, destroyed all the fish. The injury the land sustained in the immediate neighbourhood was very considerable."*

In 1805 there were again several gaps, and the whole together, between Winterton and Happisburgh, measured nearly a mile. Mr. William Smith was engaged to repair them, and the way he set about it "was eminently characteristic of his qualities as an engineer. After considering a variety of plans which had been proposed for stopping the breaches by timber! by stone! by clay banks! &c., he examined the operation of the tides and storms on the coast, compared the levels of the high and low parts, and finally proposed to make all the new artificial embankments as like as possible to the *natural embankments* thrown up by the sea [and wind] on the same coast, to make them of the same materials, and to give them such directions as might best shelter the new work by the old. A plan so simple was almost rejected with ridicule, till, by walking on the sea-shore and pointing out to his amazed companions how ineffectual and short-lived was the resistance offered by solid constructions to the rage of the sea, and how permanent was the power of sloping banks of sand and pebbles, in particular directions, to exclude the ocean which [together with the wind] had formed them he convinced the most sceptical. . . . By watching the aggregation of sand and pebbles on the shore, he found that, at particular seasons and by unusual storms, the bed of the sea was disturbed, and the sand became covered by pebbles or 'shingle' scattered with much uniformity. These shingle-beds were effective in binding down the sand which would otherwise have drifted with the wind, and he resolved in this respect to imitate his great teacher—Nature. Accordingly carts in great numbers were employed in removing sand and making great mounds across the gaps, and then, especially when the tides threw up 'shingle,' the sandy bank was sealed down with a bed of pebbles. On these unresisting slopes the mightiest storms of the German Ocean now break harmless, and a very slight annual charge is sufficient to maintain the form and substance of the work. . . . After the sea breaches

* Hewitt's Essay, "On the Encroachments of the German Ocean," etc., p. 35 (1844).

were effectually stopped, Mr. Smith was able to suggest to the proprietors of the marsh lands which had been thus benefited, effectual methods of draining (chiefly by mills throwing up the water into rivers) and improving them. In superintending the sea breach repairs and regulating the assessments to pay for this work, and in the construction of water-meadows for Mr. Coke and other persons, Mr. Smith spent a portion of every year, from 1800 to 1809, in Norfolk and Suffolk."

The repairs of the breaches in the sand hills, between Winterton and Happisburgh, extending altogether over a mile in length, as previously mentioned, were accomplished in 1805, in almost a single summer; and thereby "the expulsion of the sea from seventy-four parishes in Norfolk and sixteen in Suffolk, which, by an act of James I., 1610, entitled "The Norfolk and Suffolk Sea Breach Act," had been declared liable to contribution."*

A large quantity of the Blown Sand, which formerly lined the coast in more or less continuous hillocks in the neighbourhood of Yarmouth, has been at various times removed, and spread over the beach sand and shingle, both on the north and south Denes.

The gardens within the town walls were rampired in 1544, with Blown Sand obtained from the hills without the gates. They were rampired a second time in 1557, and a third time in 1587.

A mound of earth 222 feet long and 32 feet broad was erected in 1569 directly E. of the Prison "Tollhouse" of Yarmouth. Another mound was afterwards built to the south, much higher than the walls of the town, on which ordnance was placed, to scour all along the Haven of Yarmouth.†

A considerable quantity of the materials forming the Denes, both at Yarmouth and at Lowestoft, is constantly being removed for ballast for vessels, a proceeding that is not altogether commendable.

* Memoirs of William Smith, LL.D., by Prof. John Phillips, pp. 50-54. (1844.)

† See Manship's History of Great Yarmouth (written 1619).

CHAPTER X. PHYSICAL FEATURES AND ANCIENT HISTORICAL RECORDS.

GENERAL REMARKS.

None of the heights recorded by the Ordnance Survey, many of which are engraved on the map, reach 100 feet above Ordnance datum, or mean sea-level. The highest record is 97 feet, at St. Margaret's Church, Lowestoft, whilst north of Yarmouth 76 feet, in the road a quarter of a mile E.N.E. of Bloodhills Farm, East Somerton, is not exceeded. From these the levels fall to the marshlands, which are little above the datum.

The physical features of this district are principally due to the large amount of denudation that has taken place since the latest of the Drift deposits, the Boulder Clay, and the overlying Plateau Gravel, were deposited; and to the infilling of the valleys, particularly the main channels of the old estuary, with alluvial matter up to about the present sea-level.

The upheaval of these Drift deposits from beneath the sea at the close of the Glacial epoch, and the general physical disturbances that then took place, were probably sufficient to cause aqueous excavating agents to rapidly carve out the principal features of the district, and to bring about the present drainage-system, the sub-aerial denudation, combined with marine action that has since taken place, causing minor modifications.

Moreover, the geological mapping of the ground, together with the information obtained during the survey, would seem to show that at the completion of the cutting-out process of the main channels of the three rivers, the Yare, the Bure, and the Waveney, these rivers united and had a common outlet at the mouth of the estuary between the land in the neighbourhood of Gorleston, south of Yarmouth, and that on the opposite side at East Caister; or possibly between land a little further eastward of those places, there being probably at that time no communication with the sea either at Lowestoft, or in the neighbourhood of Horsey, between Winterton and Eccles.

Since the estuary and main channels have to a large extent been silted up, and a considerable amount of land that formerly extended beyond the present coast has been swept away, the sea would appear to have gained upon, and occasionally to have forced its way into, the upper extremities of the eastern branches of the Bure Valley, now drained by the Hundred Stream or River Thurne; and also to have forced its way, in like manner, through the upper or eastward portion of the valley or channel at Lowestoft, the stream formerly in which would appear to have been a tributary to the main channel of the Waveney; similarly to the smaller stream at Gunton, which flows westward inland away from the coast, its present eastward extremity being at too high a level for the sea to force its way through. On reference to the

map it will be observed that the narrowest portion of this valley, at Lowestoft, is near its present seaward extremity, whereas its broadest part, or former mouth, is inland, where Oulton Broad now is, and adjacent to the Waveney Valley. This leads up to the following inquiry as to the formation of the Broad.

ORIGIN OF THE BROADS.

The Broad or Lakes in this district apparently vary in age as well as in method of formation (*see p. 4*).

Breydon Water, the largest, is in the middle of the marshes W. of Yarmouth, and resembles a lagoon rather than a lake. It is tidal, and has a channel through it, which averages about 10 feet in depth at low water, when a considerable portion of the rest of the Broad is more or less dry. The widening-out of the confluent rivers, the Yare and the Waveney, together with their junction with the Bure, and the influx of the tides, has contributed to the formation of this Broad, which occupies a hollow place in the Alluvium, and is underlain by about 140 to 150 feet of recent estuarine deposits.

Ormesby, Rollesby, and Filby Broad; Fritton Decoy; Flixton Decoy; Oulton Broad and Lake Lothing respectively occupy the site of subordinate valleys, and are probably not so recent in age as the majority of those that are differently situated, and which occupy hollow or low places in the marshes. All the Broad above-mentioned were probably formed in nearly the same manner, by bars being formed across the outlets of the valleys in which they lie, during the silting up process of the main channels. These, therefore, in all probability, date back to the times when the main channels formed branches of the estuary.

Fritton Decoy is the most picturesque and most beautiful Broad or lake in East Anglia, as well as the deepest. It is of an irregular serpentine shape, over 2 miles in length, and from about 9 to 13 chains in width. 133 soundings were taken in various parts, and the deepest was $15\frac{1}{2}$ feet. Over a large portion the depth is from 12 to 15 feet, near the margins from 6 to 8, and close to the outlet from 5 to 6. The level of the marsh adjoining the water in the upper part is not quite $4\frac{1}{2}$ feet above Ordnance Datum;* consequently the bottom of the Broad over a large area is at least from 7 to 11 feet beneath that level.

Lowestoft is supplied with water from Fritton Decoy, the waterworks being at the extreme upper end.

Ormesby, Rollesby, and Filby Broad, is another beautiful sheet of water. It is of a most irregular shape, with three branches or arms on either side, is nearly 3 miles in length and from about 7 to 15 chains and more in width; and between the extremities of the arms, on either side, $1\frac{1}{2}$ miles. It is the next deepest Broad

* See 6-inch Ordnance Map.

to Fritton. 167 soundings were taken, and the greatest depth was found to be $11\frac{1}{2}$ feet. Over a large portion, it is from 8 to 11 feet, and near the margins from 4 to 6. The surface of the water in 1879 was 3·7 feet above Ordnance Datum: * consequently the bottom of the Broad, for a considerable extent, is about $4\frac{1}{2}$ to 8 feet beneath that level.

Yarmouth is supplied with water from Ormesby Broad, the waterworks being adjacent to the Broad, on the northern side of Ormesby Common. The main pipe is upwards of 8 miles in length.

Oulton Broad is another rather deep lake, that is to say, in comparison with the many very shallow Broads in East Anglia; and is perhaps the most occupied of any in the district. Yachts and other craft are frequently there in abundance, and often present a gay and lively scene. Lake Lothing, which is, or rather was, a continuation of the same sheet of water as Oulton Broad, is now, and has been for a long time, separated from it by an artificial causeway or dam. The eastern part is utilized as a harbour, and the whole is tidal, forming a backwater to scour the harbour, and to prevent a bar forming across its mouth.

The other principal Broads in the district, *Horsey Meer*, *Martham Broad*, and *Heigham Sound*, are very shallow; and rest on, and are more or less surrounded by, alluvial deposits. They may possibly occupy hollows that have either been excavated out of the Alluvium, or have never been entirely silted up. It is well known that during historical times these Broads and the surrounding area have frequently been overflowed by irruptions of the sea.

THE ROBBERDS AND TAYLOR CONTROVERSY.

Much valuable information was evolved during the friendly controversy between Mr. J. W. Robberds and Mr. R. C. Taylor on the geology and history of the Eastern Valleys of Norfolk, which created a considerable amount of interest at the time it took place (1826, 1827), throughout this district, to which it applies, as well as elsewhere. MR. TAYLOR admitted the accuracy of the historical portion of the observations published by MR. ROBBERDS, but combated the geological portion.

MR. ROBBERDS contended that the North Sea was 40 feet higher than at present, and occupied these eastern valleys at that elevation, basing this assumption erroneously upon the evidence of the marine shells that occur in the Crag or Pliocene deposits, on the sides of the valley in the neighbourhood of Norwich at about that elevation, and which he thought were comparatively recent beach-deposits, resting on the slope of the valley. MR. TAYLOR, however, who had made a special study of the Crag during 17 years, correctly contended that these marine shells did not belong to a recent beach, but formed part of the Crag.

The following observations are taken from MR. ROBBERDS' essay "On the Eastern Valleys of Norfolk," which contains much information of an

* See 6-inch Ordnance Map.

interesting and antiquarian character, gleaned from ancient historical records:—

The historical proofs of the former presence of the sea in these valleys may be derived from four sources: current tradition, remains of antiquity, etymology of place-names, and records of the changes that have taken place during the last eight centuries.

"Tradition, although no safe authority in matters of detail, is still always founded, in its main points, upon actual facts, and transmits, though often in imperfect and distorted forms, the memory of ancient events or local circumstances. In the present case it has recorded, that the sea once came up to Norwich; and the same saying is equally prevalent, with respect to the castle of Bungay on the Waveney, and other points in some of these vallies. Nor are these merely oral traditions; they have been preserved in a singular document of great antiquity, viz. the map, deposited in the town chest of Yarmouth, and of which a copy is published in Ives' *Garianonum*. The topographical inaccuracies, not to say absurdities, of this chart are so glaring, that I refer to it for no other purpose than to prove, that, many centuries ago, there prevailed a confused notion, that these vallies were, in earlier times, filled by the waters of the German Ocean . . ."

"In the marshes between Burgh Castle and the opposite rising grounds, have frequently been discovered parts of anchors, rings and other pieces of iron," (Ives, p. 9) which were evidently appurtenances of ships, and which indicate the spots, where they were found, to have been permeable to maritime vessels, since the art of navigation has been known to man. But the surest land marks in such an enquiry, are the sites of the Roman forts. . . . Within a comparatively short space, we find the vestiges of three of these frontier posts, which particularly claim our attention; these are, at Caistor, about three miles to the north of Yarmouth—at the well-known ruins, called Burgh Castle—and at another Burgh, a few miles farther to the south, generally distinguished by the appellation of Whitaker Burgh, from the name of the adjoining village. Spelman considered this [Caistor] to be the ancient *Garianonum*, which Camden and other antiquaries in his train, have placed at Burgh Castle.

Many circumstances have led me to believe, that Whitaker Burgh was the *Garianonum* of the Romans. . . ."

"The only information, which we derive from history, respecting this station, is, that it took its name from, and therefore probably stood on, or near, the *Gariensis*. . . . What then was the *Gariensis*? Modern nomenclature has confined the name of Yare to the narrow stream, that flows between Norwich and Yarmouth; but this is no proof that the original name was not more extensively applied. In the course of the changes which this district has undergone, it was natural, that the principal stream should retain the ancient appellation of the whole æstuary, and that the other branches should be distinguished by new names. In those names we find no traces of a Latin origin. . . ."

"The walls of Burgh Castle are among the most perfect specimens of Roman building in this country, and the coins found there are principally those of the latest emperors . . ."

"On the northern side of Yarmouth there is a considerable tract, now divided into the two hundreds of East and West *Flegg*. This again is an Anglo-Saxon term of the same import as our modern English word *Flat*, the German *Fläche* (with which it nearly agrees in sound), and the Dutch *Vlaakte*. The name is by no means descriptive of the present appearance of this district; but when the adjacent vallies were overspread by navigable floods, it was perfectly appropriate, and would naturally suggest itself, as in later times, the appellation of Borough *Flats* has been given to the level marshland near the junction of the Waveney with the Yare."

Speaking of Domesday Book, Mr. ROBERTS remarks that "this authentic register of every description of property at that period existing in the kingdom, enables us, in many instances, to trace, with precision, the changes which seven centuries have produced; and it furnishes at least one piece of curious and valuable information, connected with the subject of this enquiry. Amongst the arable and pasture lands, the heaths, the sheep-walks, the woods, the mills and the other items, which then formed the substantial wealth of the district,

we find also a considerable number of salinæ or salt works. These could only have been reservoirs into which the brine of the sea was admitted at the flow of the tide, and retained for the purpose of making salt, by the evaporation of the water in which it was held in solution. This simple method of preparing that useful commodity was in early practice among the Romans, and by them it was most probably taught to the conquered Britons. . . .”

“The following are the salt-works mentioned by the Domesday Book on the eastern side of Norfolk and in the adjacent parts of Suffolk.”

Caistor -	-	-	-	29	Clipesby -	-	-	-	1
Mantby -	-	-	-	11	Somerton -	-	-	-	3
Runham -	-	-	-	19	Winterton -	-	-	-	1
Herringby -	-	-	-	6	Burgh -	-	-	-	2
Stokesby -	-	-	-	3	South Walsham	-	-	-	3
Thrickby -	-	-	-	6	Halvergate -	-	-	-	1
Filby -	-	-	-	9	Burgh Castle -	-	-	-	3
Rollesby -	-	-	-	1	Gorleston -	-	-	-	3
Hemesby -	-	-	-	2					

From the above list “it will be seen that they existed in almost all the villages of the Flegg hundreds, but most abundantly in those which occupy the line of the southern escarpment from Stokesby to Caistor; even Halvergate and South Walsham, which are seven or eight miles distant from the present coast, and to which no brine could ever have been conveyed through the circuitous channels of the now existing rivers, had their salt pans; and in every instance they were situated on the immediate borders of some part of these vallies, which are thus proved to have been overflowed by sea water in the year 1086, when the survey of Norfolk was completed.

. . . It must also be remarked that Domesday Book gives no account of any of those extensive tracts of marsh land, now belonging to these villages.”

“All our historians and topographers, who make mention of Great Yarmouth, concur in stating, that the site of that populous town was, at the beginning of the Christian era, a sand bank in the entrance of an arm of the sea; that this shoal became an island, on which fishermen first pitched their summer tents, and by degrees established a permanent abode; and that the growth of this community kept pace with the increasing security of the situation. Spelman, in his *Icenia* [*Reliquiæ*, p. 154], says that this ground first became firm and habitable about the year 1008. Domesday Book refers to a survey made by Edward the Confessor, at which time, about A.D. 1050, Yarmouth is said to have had seventy burgesses. Yet as its name does not occur in the Saxon Chronicle, we may conclude that it did not exist at the period of Sweyn’s irruption,* for he must have passed it on his way to Norwich, and it could not have escaped his rapacity, if it had been an object worthy of plunder. Swinden, whose history of this place is compiled entirely from local records, informs us (pp. 20 and 373), that the ground on which it stands, was an island till about . . . 1347. At that period the northern channel between Yarmouth and Caistor, known by the name of Grub’s Haven and Cackle Water, which began to be choked with sand soon after the Conquest, was entirely closed; and “many thousand acres of marsh or meadow land became dry (which had before constantly been overflowed by the sea) and in time produced good pasturage for cattle.””

“Kirkley road . . . was a much frequented port till the 14th century, when the citizens of Yarmouth obtained a charter, which extended their jurisdiction over it in the 46th of Edward III. A.D. 1373. From that time its importance declined; no exertions were used to remove the bar of sand and shingle which accumulated at its entrance, and by which the navigation was gradually impeded; but it was not till the beginning of the last century, that all communication was cut off between the sea and Lake Lothing, for it

* “The Saxon Chronicle relates this event in terms so explicit, that they cannot be mistaken. ‘A.D. 1004. This year came Sweyn with his fleet to Norwich,’ [Ingram, p. 177.] is a literal translation of the record.”

appears, that in the year 1712, the proprietors of the marshes along the course of the Waveney, embanked this isthmus, in order to prevent the inundations to which their lands were subject from high tides. . . .”*

“The phenomena of nature and the works of man—the relics of past ages—the land-marks of progressive civilization—and the authority of historical records—all concur to prove that the eastern valleys of Norfolk were formerly branches of a wide æstuary.”†

The following observations were made by MR. R. C. TAYLOR in 1827 :—

“About the year 901 the boundaries of the counties and hundreds were defined, and the limits of parishes and manorial jurisdictions were determined. These provincial sub-divisions, and even the estates into which they were further appropriated, are carefully registered in Domesday Book. It happens, without any exception, that all the boundaries of the counties, hundreds, and local jurisdictions of this district, are the rivers which wind through the various marshy valleys. It follows, therefore, that the streams had, as early as the year 900, formed themselves channels, adapted to mark the boundaries of property; which channels have continued to our times, with little alteration, except at their immediate outlets.”

“They were gradually embanked, as cultivation proceeded and the value of land increased. We know that the river which divides the hundreds of Flegg and Happing was embanked previously to 1274, near the abbey of Holm; for in that year occurred a dispute about the right of fishing from the river’s banks.”

“One mode of estimating the comparative elevation of the waters is distinctly furnished in the causeways or dams, which were early constructed across the estuaries. The bridge called Weybrigg, at Acle, and the great causeway connecting with it, were certainly in existence in the eleventh century; and we find that payments were made towards their *repair* in 1101, and succeeding years. This causeway is so little above the present level of the river and marshes, that even in our own times it has been repeatedly overflowed. At any rate, it establishes the negative fact, that no very important change has taken place in seven centuries at a point adjoining the broadest part of the main æstuary, and only eight miles from the sea.”

“It is stated in a preceding page, that to a limited extent the channels of the Yare and other rivers were wider than at present; evinced by the peaty margins and the deposit of silt in the undisturbed recesses. These circumstances are confirmatory of the reduced supply of tidal waters, and show that the streams have gradually accommodated themselves to the volume of water which they have to convey . . .”

“The *Saline*, mentioned in Domesday Book, were chiefly situated on the north shore of the main æstuary, within three miles of its mouth; 39 of them being at Caister, and 30 more in the two contiguous parishes. None occur in the Norwich, Beccles, or Kirkley valleys; and as it does not appear that saltworks were mentioned *after* the Confessor’s time, it is probable that the north entrance commenced silting up shortly after, so as to exclude the requisite admission of sea water for such works.”

“Some uncertainty prevails with respect to an open communication between the ocean and the extensive watery flat near Horsea. Mr. Robberds’ map shows two points by which the sea appears to have penetrated into this flat. Local records are silent upon that head. There is no mention of saltworks upon its borders, or of any other circumstances positively implying such an event. From the remotest period to which we can refer, it has been a branch of the main æstuary of the Garienis, and by this channel the drainage of the district is effected. The soil is composed chiefly of peat, rather than of ooze; the first characterizing the upper parts of a valley, the latter its mouth. Whether by the gradual external wearing away of this coast, the sea

* “Gillingwater’s History of Lowestoft, p. 32.”

† Geological and Historical Observations on the Eastern Vallies of Norfolk, by J. W. ROBBERDS, jun., 8°, *Lond.* and *Norwich*, 1826, pp. 19–62.

approached so near this flat as occasionally to overflow the intervening bank of sand; or whether that bank results from the abrasion of the cliffs to the north, and blocks up an ancient inlet,—there are scarcely sufficient data to determine. The existence, therefore, of those northern channels, although not improbable, must remain conjectural.

"This inquiry suggests views of cause and effect adequate to the admitted extent of the change, which are briefly these:—"

"That as long as the ocean-currents set unrestricted into these æstuaries, it was in sufficient quantity to expand over and fill them; the elevation being limited by the height of the tides at the time, and the depth by the greater or less accumulation of oozy sediment."

"That there was from the remotest period, through the local causes which have been detailed, a progressive decrease in the volume of this water, and by consequence a reduction, in an equal ratio, of the power to maintain an open mouth."

"That the same causes which finally closed the æstuary at Caister, were simultaneously operating to bar the ancient haven at Kirkley, and probably to exclude the sea from the more northerly inlets."

"That as soon as the admission of the tide was limited to one narrow and obstructed inlet, the quantity thenceforward was so trifling that 'many thousand acres became dry, and in time good pasturage for cattle.' With the assistance of embankments, the entire level of marshes became firm land; rich vegetation covered its surface, and the rivers were restricted to their deep channels."

"This is the solution of that change whose traces are yet so perceptible; a solution compatible with all the real circumstances, physical and historical, with which the subject is connected." *

* On the Geology of East Norfolk, etc.; by R. C. Taylor, pp. 38-41. Reprinted from *Phil. Mag.*, ser. 2, vol. i., pp. 429-432.

APPENDIX I. WELL-SECTIONS.

This Appendix contains for the most part a description of well-sections procured whilst I was in the district, arranged alphabetically according to localities under each county.

The most interesting is the deep boring at Yarmouth, which revealed the occurrence of a considerable thickness of Eocene beds underlying the district, the presence of which, until it was made, was unknown. Referring to this boring, Prof. PRESTWICH says:—"Unfortunately this spirited undertaking was not successful so far as the water-supply was concerned; but geologists are nevertheless indebted to Messrs. Lacon and Co. for having preserved a full record of the boring, and specimens of the strata penetrated, which have brought to light some geological facts of interest."* Remarks on some of the beds passed through will be found on pp. 6, 8, 9, 64.

The thicknesses and depths are given in feet.

NORFOLK.

HEMESBY.—Brickyard, $\frac{3}{4}$ mile S.S.W. of the church.

[Glacial.] Loam, unstratified and mottled grey and brown, with a little grey clay at the base, and then sand, 14 feet.

HEMESBY.—About 12 chains N. of the church. 1878.

[Glacial Drift.]	Loamy clay, mottled brown and grey	-	11	} 16 +
	Buff sand (patch in clay probably)	-	5	
	Grey loamy clay	-	?	

HEMESBY.—Near railway-bridge, $\frac{3}{4}$ mile W. by N. of the church.

Water rose 5 feet.

[Glacial Drift.] Reddish-brown loamy clay, 16 feet.

HORSEY.—On marsh, $\frac{3}{4}$ mile S. of the church, and about 150 yards, or more, eastward of the road.

[Alluvial and Estuarine Deposits.]	Black "ooze" and silt, with a bed of shells	-	-
	6 feet down, and a trunk of oak at 10 feet	-	19
	Sand	-	1

MARTHAM.—At level-crossing close to the railway-station.

[Glacial.]	Brown loam	-	-	-	21
[Pebbly Series.]	Sand. Water got at the bottom	-	-	-	2

At the next two level-crossings the wells are 30 feet and 13 feet respectively in depth, mostly through Lower Glacial loam into the underlying sand.

ORMESBY ST. MARGARET'S.—In the angle of the road, $\frac{5}{8}$ mile E. of the church.

Water rose to within 6 feet of the surface, and has remained at about that level; but once it rose to the surface.

Sand	-	-	6	} 40
Boulder Clay	-	-	34	

* *Quart Journ. Geol. Soc.*, vol. xvi., p. 449.

ROLLESBY.—Clay-pit, $\frac{1}{4}$ mile W.N.W. of the church.

		Thickness.	Depth.
[Glacial Drift.]	Boulder Clay	18	18
	Hard conglomerate	$\frac{1}{2}$	18 $\frac{1}{2}$
	Red gravel	3	21 $\frac{1}{2}$
	White sand	3	24 $\frac{1}{2}$
	Loam	5	29 $\frac{1}{2}$
[Pebbly Series.]	Stony brown loam	15	44 $\frac{1}{2}$
	Gravelly sand, with water	5	49 $\frac{1}{2}$

WAXHAM.—At corner of road N.E. of the church. 1879.

Water rose 3 feet.

[Glacial.]	Brown loam	10	} 13
[Pebbly Series.]	Sand	3	

WHEATACRE.—Board School, $\frac{3}{4}$ mile S.E. of the church. 1877.

[Plateau Gravel.]	Sandy and gravelly brown loam	6	} 12
Boulder Clay	-	6	

YARMOUTH.—Messrs. Baly, Sutton & Co.'s Manure Works. 1869.

Communicated by the manager, with a tube of specimens, from a depth of 16 feet to the bottom.

Boring of 1 $\frac{1}{2}$ inches diameter.

Water overflowed the top of the pipe, which was 4 feet above the ground, for 3 or 4 days. The water was bluish, and the sediment from it sandy. It was used for 6 or 7 years, but was given up on account of stones and sand being constantly pumped up.

[Recent and Estuarine Deposits.] Shelly brown sand, with a little loam and soil at top, 70 feet.

The uppermost and the lowermost samples of the sand are the darkest. Small fragments of shells occur, and are plentiful in the upper and lower specimens, a piece of *Cardium* being identifiable near the bottom of the tube.

YARMOUTH.—Sir E. Lacon & Co.'s Brewery. 1840. In the yard, which is 20 feet above Ordnance datum.*

Shaft 22 feet; the rest bored.

The following detailed description is that given by PROF. PRESTWICH,† based upon his examination of the specimens. These are still preserved at the brewery, in the box originally made for them, which contains three trays divided into compartments, on each of which is recorded the depth at which the specimen in it was obtained. Through the courtesy of Mr. Nightingale, I carefully examined all these with Prof. Prestwich's account in my hand.

"One column," says PROF. PRESTWICH, "gives the specimens as read off previous to my having formed any definite conclusion; and in another column is added the geological structure which the examination of the specimens in conjunction with the coloured section led me to surmise. From the nature of the work, the shells are necessarily small or fragmentary."

		Depth.
	Blown sand and shingle, about 50 feet.	
Recent Estuarine Deposits. 120 Feet.	1. Coarse light-coloured sand, with 1 specimen of <i>Ostrea edulis</i> ; 2 of <i>Cardium edule</i> , 1 each of <i>Corbula nucleus</i> [gibba], <i>Tellina balthica</i> , and <i>T. planata</i>	58
	2. Light-grey clay, with a few pebbles of quartz, fragments of <i>Cyprina islandica</i> , 1 <i>Tellina</i> , and 1 fragment of <i>Pecten opercularis</i>	109
	3. Yellowish shelly sand, with fragments of small <i>Tellina</i>	111
	4. Fragments of comminuted shells, none perfect	113
	5. Light-coloured shelly sands	123

* Kindly communicated by the Director-General of the Ordnance Survey, Dec. 1884.

† *Quart. Journ. Geol. Soc.*, vol. xvi., pp. 450, 451 (1860).

Recent Estuarine Deposits. 120 Feet.	{	6. Light-grey shelly sands - - -	150
		7. The same, coarser, with concretions and a few flints - - -	156
		8. Laminated micaceous grey clay - - -	158
		9. Light-brown clay - - -	160
		10. Grey clay and sand, with shells; <i>Tellina</i> (same as in No. 2), 1 fragment of <i>Mytilus</i> <i>edulis</i> - - -	161
		11. Grey clay, with undeterminable fragments of shells; 1 valve of <i>Balanus</i> - - -	166
		12. Light-brown clay and small light-coloured concretion (like those in the London Clay) - - -	170
		13. The same, one concretion - - -	180
		14. Tough brown clay - - -	190
		15. The same, slightly greyer - - -	200
London Clay. 310 Feet.	{	16. The same, one concretion - - -	210
		17. The same, slightly variegated - - -	220
		18. Brownish-grey clay - - -	230
		19. Dark-grey clay - - -	240
		20. The same, with 2 lumps of iron-pyrites and 2 small calcareous concretions - - -	240-50
		21. Grey clay - - -	250
		22. The same, darker and more compact - - -	260
		23. The same, " " " " - - -	270
		24. The same, " " " " - - -	280
		25. The same, browner; iron-pyrites - - -	291
		26. The same, with wood and decomposing iron- pyrites - - -	294
		27. Brown clay - - -	300
		28. Light-grey sandy clay - - -	309
		29. Greenish sandy clay - - -	320
		30. Streaked brown clay - - -	330
		31. Greyish-brown clay - - -	340
		32. Micaceous sandy clay - - -	350
		33. Same as 31 - - -	358
		34. " " 32 - - -	370
		35. Brown sandy clay - - -	380
		36. Grey clay, with decomposing iron-pyrites - - -	389
		37. Brown clay - - -	390
		38. The same - - -	400
		39. Brown micaceous sandy clay - - -	410
		40. Brownish sandy clay - - -	420
		41. The same - - -	430
		42. Dark-brown sandy clay - - -	440
		43. The same, with soft green grains - - -	450
		44. Tough brown clay - - -	460
		45. The same - - -	470
		46. Fragments of soft septaria - - -	475
Reading Beds, 46 feet.	{	47. Grey clay, with lignite - - -	480
		48. Tough brown clay - - -	490
		49. Streaky dark-grey clay - - -	500
		50. Grey clay and green sand - - -	505
		51. The same, more mixed - - -	510
		52. The same, with more green sand - - -	515
		53. The same, with less green sand - - -	520
		54. Pure dark-green sand - - -	525
		55. The same, more clayey, and with small dark green-coated flints - - -	526
		56. Chalk with flints, 70 feet - - -	597

The thickness of Chalk pierced has inadvertently been given as 57 feet in Prof. Prestwich's description, instead of 70. I was informed at the Brewery that the boring reached a depth of either 596 or 599 feet.

SUFFOLK.

ASHBY.—On low ground near the church.

[Glacial.] Sand, with a little silt overlying, 12 feet.

BLUNDESTON.—Warren Farm.

[Pebbly Series.] Sand and gravel, to water, 16 feet.

CARLTON COLVILLE.—Brickyard, $\frac{1}{2}$ mile E. of railway-station.

[Glacial Drift.] { Boulder Clay - 12 } 52 Feet.
[Sand - 40]

FRITTON.—The Rectory.

[Glacial.] Silt, sand, and a little gravel, to water, 28 feet.

KESSINGLAND.—On the northern side of the road leading to the beach,
 $\frac{1}{2}$ mile E. by S. of the church. 1879.

Water got at the bottom.

Soil	-	-	-	-	-	-	4
[Glacial.] Brown sand	-	-	-	-	-	-	2
[Chillesford Beds.] Laminated clay and sand (micaceous), the clay stiffer downward	-	-	-	-	-	-	6
							<u>12</u>

LOUND.—At Lound Farm. Now disused.

[Glacial.] Sand and gravel, to water, about 50 to 60 feet.

LOWESTOFT.—Brickyard, $\frac{1}{4}$ mile W.S.W. of St. Margaret's Church.

[Glacial Drift.] { Boulder Clay - 2 }
[Buff Sand - 30 } 33
[Pebbly Series.] Shingle, with water - 1 }

SOMERLEYTON.—Somerleyton Hall.

The well is 9 feet in diameter and 55 in depth, and the level of the water in it remains at 8 feet above the bottom, except when pumped. From 7,000 to 8,000 gallons a day used.

Another well near the Rosery in the grounds.

[Glacial.] Sand - 50 }
[Pebbly Series.] Coarse gravel - 10 } 60 Feet.

SOMERLEYTON.—At the Village Green.

[Glacial.] Stony loam - 15 }
[Pebbly Series.] Sand and gravel - 30 } 45 Feet.

Another well, containing a pump, from 50 to 60 yards from the above, is from 45 to 47 feet in depth. Some pipe-clay (Chillesford Clay?) near the bottom.

SOMERLEYTON.—Mr. Hubbard's Cottages.

Said to have been sunk through sand, to a depth of $61\frac{1}{2}$ feet.

SOMERLEYTON.—Two wells about $\frac{1}{4}$ mile S. of the church.

[Pebbly Series.] Sand and gravel, about 30 feet.

The well-sinker who supplied me with the above information stated that the water in the neighbourhood of Somerleyton is generally met with in clean sand, lies at one level, and only varies a foot or two feet between dry and wet weather. When a well gets dry, he said, a wooden tub is sometimes driven about 2 feet into the bottom, and water by that means obtained.

APPENDIX II.

TRIAL-BORINGS, MADE BY THE GEOLOGICAL SURVEY. By C. REID.

DESCRIPTION OF THE TOOL USED.

For some years the Geological Survey of Belgium has used light boring-tools to test the extent of the different Tertiary beds. This is the only means by which the boundaries of the formations can be traced, with any degree of certainty, in districts where there are few or no sections, or where there is a wide extent of superficial deposits, thick enough to prevent ditches reaching the underlying rock.

It was not till some time after the completion of the maps of Norfolk and Suffolk that it was decided to give the Belgian boring-tools a trial in England. A set of the tools was obtained, and while in Belgium, studying the correlation of the Pliocene deposits, I had the advantage of learning, from Messrs. VAN DEN BROECK and RUTOT, the practical working of the apparatus.

The tool consists essentially of a spiral auger about $2\frac{1}{2}$ inches in diameter, very similar to an ordinary gimlet, but with two threads; several short square rods to lengthen it; and a T-shaped handle. A jumper or chisel is also provided, but in practice is very seldom used.

In operation the auger is screwed into the ground till it is full, or works stiffly, and is then lifted out. The material thus brought up in the grooves is not nearly so much broken as might be expected. Good samples and plenty of fossils in a recognizable state can be obtained, the smaller species being often perfect.

So far the tool is no way different from an auger often used by well-sinkers in this country. But one of the most important points, when boring-tools are used for survey-purposes, and many borings are made in a day, is that the whole apparatus must be very light, so that it can be carried and worked by two men. As lightness is essential no triangle or pulleys can be used, the tool being raised by hand. When the beds are soft there is no difficulty, and the tool can easily be lifted out. Sometimes, however, it is found that the auger has been screwed too deep into stiff clay, or has become fixed by a stone fallen from above. No apparatus being available, and the rods being too slender to allow of any violent usage, the auger cannot be extracted by main force, and must be turned backwards, in fact unscrewed. Ordinary boring-tools will not allow of this, for any backward turn immediately unscrews the joints. To obviate this difficulty a special form of joint is used. In this the end of each rod is flattened on one side, so that it forms a splice with the next rod. These are placed together, and a loose cap, supported by a collar on the upper rod, is screwed over the joint to a male screw on the lower rod. It is difficult to describe this without diagrams, but a full description and illustrations will be found in a paper by M. E. VAN DEN BROECK and A. RUTOT.*

This joint allows the auger to be worked either forward or backward without the rods becoming unscrewed.

By this method of boring, a depth of 17 feet can be reached without any necessity for unscrewing the rods, except to lengthen them. Beyond this depth the rods must be divided, the work is much slower, and three men are needed. A depth of 33 feet can be attained, if the beds are sufficiently firm for the boring to be kept open without a lining-tube.

On returning to England the first use to which the tools were put was to make a series of borings between Cromer and Kessingland, to test the thickness and character of the different Pliocene beds. Later experience has shown that this was one of the most difficult districts that could have been selected for boring. Even now, with more practice in the working, it is doubtful whether many of the earlier borings could have been carried deeper without the use of lining-tubes.

* *Bull. Soc. belg. géol.*, t. ii., *Mem.* p. 135 (1888).

One of the first results of the borings was to prove that there is very little stiff clay in the Pliocene beds, and that the whole deposit is so loose and full of water that sand and mud flow in and stop every boring before it has reached the full depth. A few borings were stopped by coarse gravels; but these are generally thin, and are not so difficult to deal with as the running sand, which accumulates in the hole till it is impossible to lift the auger.

The following sections show the result of such of the borings as are within the district described in this Memoir. To them have been added some further trial-holes made at Pakefield and Kessingland, toward the end of 1888, to test the relations of the estuarine or fluvial Forest-bed Series to the Chillesford Clay and Crag.

RECORD OF THE BORINGS.

The accounts of the borings are taken from north to south, and the figures stand for feet.

Winterton.—Nine chains N. of the church, on the marsh, and about 6 feet above Ordnance Datum. Oct. 1886.

Alluvium.	{ Peaty soil, &c.	-	-	4
	{ Grey silty clay	-	-	3½
	{ Brown silty clay	-	-	2½
	{ Silty sand	-	-	1
	{ Sand and gravel, full of water	-	-	3
				<hr/>
				14
				<hr/>

Scratby.—Opposite the Gap, and 2 feet above extreme low-water. Oct. 1886.

Boulder Clay; 11 feet.

Sand, full of water; 1 foot.

This boring was made in the hope of reaching Pliocene beds below the Boulder Clay. The sand touched was full of water, and neither could it be penetrated nor could samples of it be obtained.

Hopton.—At the foot of the cliff opposite League Hole. Oct. 1886.

Boulder Clay; 7 feet.

Sand; 5 feet.

Hopton.—Nearly half a mile S. of League Hole, opposite the highest part of the cliff. Oct. 1886.

Forest-bed Series.	{ Dark-blue unctuous clay; 6 feet.	
	{ Lighter-coloured clay with race; 1 foot.	
	{ Sand.	

Corton.—About half a mile N. of the Gap, and opposite a depression in the cliff, commencing immediately above the rootlet-bed. Oct. 1886.

Forest-bed Series.	{ Peat	-	-	-	¼
	{ Unctuous bluish-grey clay	-	-	-	3½
	{ Hard whitish marl or clay, with a few small stones	-	-	-	½
	{ Ferruginous gravel, with quartz and quartzite	-	-	-	3½
					<hr/>
					8
					<hr/>

Corton.—Eleven chains N. of the Gap. Three feet above high-water springs. Oct. 1886.

Lower Boulder Clay. Brown loam, blue at the base; 6 feet.

Forest-bed { Ochreous sandy loam, with carbonaceous matter; ½ foot.

Series. { Gravel; 2 feet.

Corton.—Twenty yards N. of the Gap, and about 3 feet above high-water springs. Oct. 1886.

Lower	{ Brown loam, with fragments of shells	-	-	4½
Boulder	{ Blue clay, with white specks (decayed flint ?)	-	-	1
Clay.	{ Brown sandy loam	-	-	1½
Forest-bed Series. Gravelly quartzose sand and gravel, with water				4½
				<hr/> 11½ <hr/>

Pakefield.—Opposite the end of the Grand Avenue, at level of high-water. Oct. 1886. Gravelly pan (in the cliff). Forest-bed Series ? 6 inches.

Chillesford	{ Laminated clay and sand, very ferruginous (in the	-	-	-
Clay.	{ cliff, 6 inches, the rest bored)	-	-	3½
	{ Sand and a little clay	-	-	1
	{ Fine buff sand, full of water	-	-	7½
				<hr/> 12 <hr/>

Pakefield.—Eight chains N. of the Lighthouse Gap. Oct. 1886.

Chillesford	{ Laminated micaceous light-blue or ferruginous clay	-	-	-
Clay.	{ and sand	-	-	13½
	{ Brown loamy sand, with thin seams of light-blue	-	-	-
	{ clay	-	-	3
	{ Sand, with water	-	-	1
				<hr/> 18 <hr/>

Pakefield.—About 9½ chains S. of the Lighthouse Gap, and nearly ½ chain S. of the northern end of the second basin-shaped hollow of the Forest-bed Series. (Black, brown, and grey laminated clay, etc.) Nov. 1888.

Chillesford Clay. Thinly-bedded micaceous grey clay and fine brown sand, with ferruginous sand in the lower part; 16 feet.

Pakefield.—About 12½ chains S. of the Lighthouse Gap, and 2½ S. of the above. Nov. 1888. Bottom of cliff of black, brown, and grey laminated clays, etc.; in basin-shaped hollow (Forest-bed Series).

Beach-sand	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
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Pakefield.—Close to the last, but slightly different. Oct. 1886.

Forest-bed	{ Peaty loam	-	-	-	2½
Series.	{ Blue loam and gravel	-	-	-	2
Chillesford Clay.	Laminated clay and sand				3
					7½

Pakefield.—About 22½ chains S. of the Lighthouse Gap, and a chain S. of the southern end of the second basin-shaped hollow, at high-water level. Oct. 1886.

Forest-bed { Carbonaceous clay;
Series. { Laminated gravelly sand; 6 feet.

Pakefield.—About 25½ chains S. of the Lighthouse Gap, and 2½ chains S. of the last section. Bottom of cliff in compact homogeneous greenish-grey unstratified clay, with race (Rootlet-bed). Nov. 1888.

Forest-bed. Bluish-grey and blackish loamy clay, with sand in the lower part; 8 feet.

Crag. Reddish sand with numerous fragments of marine shells; 2 feet.

Kessingland.—A chain S. of the parish-boundary. 1886.

Forest-bed. Carbonaceous clay with scattered stones; a foot.
 ? Blue sand with water; 4 feet.

Kessingland.—About 32½ chains S. of Pakefield Lighthouse Gap, and 7 chains S. of the last but one. Bottom of the cliff in greenish-grey clay (Rootlet-bed) stratified, with sand in the lower part. 1888.

Forest-bed Series.	{	Irregularly stratified very carbonaceous gravelly	
		brown and grey sand - - - - -	8
		Grey sand with fragments of shells - - - - -	2
		Gravel, etc. - - - - -	1

Kessingland.—Opposite Cliff Farm, a foot below high-water-mark and 5½ feet below the top of the rootlet-bed. 1886.

Forest-bed Series.	{	Unstratified blue clay - - - - -	7
		Gravelly clay - - - - -	¼
		Carbonaceous clay, with vegetable impressions (P roots) - - - - -	¼
Blue sandy silt, grains very small, carbonaceous grains, but no other fossils (perhaps Chillesford Clay) - - - - -			2½
			<hr/> 10 <hr/>

Kessingland.—S.E. of Cliff Farm and 2 chains S. of the last. Commenced a foot below the top of the rootlet-bed and about the level of high water. 1886.

Forest-bed Series.	{	Blue clay with rootlets - - - - -	4½
		Brown sand - - - - -	2
		Brown sand, with clay seams and a few stones - - - - -	½
		Blue-black clay, with carbonaceous matter and a bad smell - - - - -	¼
		Sand - - - - -	¼
		Stiff marsh-clay - - - - -	¼
		Sandy gravel and angular gravel - - - - -	2
Chillesford Series ?	Sand - - - - -	1½	
			<hr/> 12 <hr/>

Kessingland.—Seven chains N. of the old Coast Guard Station. At the level of high-water springs. 1886.

Forest-bed Series.	{	Light greenish-grey clay - - - - -	1
		Buff sand - - - - -	1
		Clay as above, a few small stones (and roots ?) - - - - -	1½
		Buff sand - - - - -	1½
		Clay as above - - - - -	1
		Buff sand - - - - -	1¾
		White clay - - - - -	⅓
		Sand - - - - -	⅓
		Brown loam and loamy sand - - - - -	⅓
Gravelly sand - - - - -		⅓	
			<hr/> 9 <hr/>

Kessingland.—Three chains N. of the Watch House. Commenced a foot below the level of the base of the rootlet-bed. 1886.

Chillesford Series ?	{	Blown sand, banked against the cliff - - - - -	2
		Buff and orange-coloured sand, the lower part full of water - - - - -	12½

Kessingland.—Beach End. About 4 chains N. of the road. Commenced 6½ feet below the level of the top of the rootlet-bed. 1886.

Blown sand	-	-	-	-	-	4
Chillesford Series ?	{	Blue clay and sand, rather ferruginous	-	-	-	1½
		White, buff, and orange-coloured sand, becoming very pale at 6 feet	-	-	-	1½
		Orange-coloured loamy sand, with a few stones in the upper part	-	-	-	4
						<hr/> 11 <hr/>

[MR. BLAKE (who was present, with MR. REID and myself, when the borings were made in 1888,) would classify the beds somewhat differently. In the second Corton section he classes the beds below the Boulder Clay with the Pebbly Series. In the second Pakefield section he suggests that the bottom sand may be Crag, and in the next two he classes the beds at the base of the cliff with the Pebbly Series, as also the upper beds of the following section. In the second Kessingland section he classes the sand and gravel at the base as Crag. W. W.]

APPENDIX III.

LISTS OF FOSSILS.

(1.) MAMMALIA. FROM THE FOREST BED SERIES AT KESSINGLAND AND PAKEFIELD.
(Revised by E. T. NEWTON, F.G.S.)

Species found.	Museum of Jas. Backhouse, West Bank, York.	Norwich Museum.	Museum of Practical Geology, London.	Dr. Crowfoot's Collection, Beccles, Suffolk.
CARNIVORA.				
<i>Ursus spelæus</i> , <i>Blum.</i> (Cave-bear, extinct)	1 skull, 2 lower jaws	-	Shaft of humerus.	—
<i>Canis lupus</i> , <i>Linn.</i> (Wolf) -	Upper portion of tibia.	—	—	—
<i>Felis</i> ? * (Tiger ?).	—	—	—	—
<i>Hyæna crocuta</i> , var. <i>spelæa</i> , <i>Goldf.</i> (Cave-hyæna).	Portions of 2 lower jaws, each with a perfect molar.	—	—	—
<i>Machærodus</i> , sp. -	Lower jaw.	—	—	—
<i>Trichechus</i> Huxley, <i>Lankester</i> (a Walrus)	Large cervical vertebra.	—	—	—
UNGULATA.				
<i>Equus caballus</i> , <i>Linn.</i> (= E. fossilis, <i>Meyer</i>) (Horse).	3 bones, numerous molars -	-	Metatarsal ? species -	9 teeth.
— <i>Stenonis</i> ? <i>Cocchi</i> (extinct) -	Lower jaw with 3 molars.	—	—	—
<i>Rhinoceros etruscus</i> , † <i>Falc.</i> (extinct) -	Portion of jaw, 9 teeth, and 8 portions of bones.	Left radius and atlas	Lower jaw with 2 teeth, and 1 tooth, and 4 bones.	Lower jaw with 4 teeth, 3 up. molars, 4 l. molars, 1 acetabulum, 1 atlas.

* In the British Museum.

† Also, in the collection of Mr. E. T. Dowson, 3 molar and 2 premolar teeth, found at Pakefield. Figured in Plate VIII., Vertebrata of the Forest Bed Series, by E. T. Newton.

Mammalia—continued.

Species found.	Museum of Jas. Backhouse, West Bank, York.	Norwich Museum.	Museum of Practical Geology, London.	Dr. Crowfoot's Collection, Beccles, Suffolk.
<i>Hippopotamus amphibius</i> , (= <i>H. major</i> , <i>Owen</i>).	2 molars, 1 unworn	-	—	1 r. lower canine, 1 r. lower incisor. —
<i>Sus scrofa</i> , <i>Linn.</i> (Wild Boar)	Large canine and atlas vertebra.	—	—	—
Bison ? - - -	L. molar, phalanx, $\frac{1}{2}$ humerus	-	Sp. ? 2 tibiae, 2 radii, 1 metacarpal. —	Right ramus, 1. jaw with 3 teeth. —
<i>Cervus elaphus</i> , <i>Linn.</i> (Red Deer)	Portion of skull and antler	-	3 bases of antlers —	Antler almost perfect, black. —
— <i>pollignacus</i> , <i>Robert</i> (extinct)	Antlers.	-	4 portions of antlers.	—
— <i>Savini</i> , <i>Dawkins</i> (extinct)	Skull and parts of antlers, 10 portions of antlers.	Portions of skulls and antlers.	Part of antler -	2 frontal bones with large portion of antlers attached, 1 piece of antler.
— <i>Sedgwickii</i> , <i>Falc.</i> (= <i>C. dicranios</i> , <i>Nesti</i> , MS.) (extinct).	9 portions of antlers	-	10 antlers, 1 very fine -	3 portions of skull with beam of antlers attached, por- tions of antlers.
<i>Cervus verticornis</i> , <i>Dawkins</i> (extinct)	2 skulls with antlers attached, 28 portions of antlers.	Portion of antlers -	11 portions of antlers, 2 l. jaws, &c.	Atlas, 5 l. jaws with teeth, 3 metacarpal bones; 1 femur.
—, sp. ? - - -	20 jaws with 3 to 6 teeth each.	Fragments of jaws with teeth.	—	—
RODENTIA.				
<i>Trogontherium</i> Cuvieri, * <i>Owen</i> (extinct beaver).	3 portions of teeth.	—	—	—

* Also, in the possession of the Rev. E. E. Montford, of Derby, right mandibular ramus, obtained from Kessingland. Figured in Plate XI., Vertebrata of the Forest Bed Series, by E. T. Newton.

Mammalia—continued.

Species found.	Museum of Jas. Backhouse, West Bank, York.	Norwich Museum.	Museum of Practical Geology, London.	Dr Crowfoot's Collection, Beccles, Suffolk.
Castor fiber, <i>Lin.</i> (= <i>C. europæus</i> , <i>Owen</i>)	Part of jaw with 3 molars and incisor.	-	-	Part of jaw with 4 l. lower grinders and incisor.†
<i>Arvicola intermedius</i> , <i>Newton</i> (extinct vole)	-	-	2 teeth, and humerus.†	—
PROBOSCIDEA.				
<i>Elephas antiquus</i> , <i>Falc.</i> (extinct) -	Lower jaw with perfect molars, 2 molars, &c.	-	-	—
— meridionalis, <i>Nesti</i> (extinct) -	3 up. and 3 l. molars nearly perfect, several imperfect.	-	2 large upper teeth.	—
<i>Elephas primigenius</i> , ? <i>Blum.</i> (Mammoth, extinct).	Upper and lower molar with 14 plates.	—	-	2 molar teeth.
—, sp. ? -	11 various bones, tibia, pelvis, femur, scapula, rib, &c.	7 portions of femur, tibia, humerus, scapula, &c.	Tusk, 49 inches long, part of jaw, humerus, part of ulna, &c.	2 vertebrae and piece of pelvis.

† Figured in Plate XII., Vertebrata of the Forest Bed Series, by E. T. Newton.

‡ Left humerus, obtained from Kessingland by J. H. B. Figured in Plate XIII., Vertebrata of the Forest Bed Series, by E. T. Newton.

Mr. E. T. Dowson, of Geldeston (near Beccles), Norfolk, has the following specimens, obtained from Kessingland and Pakefield, in his collection:—Bison ? (astragalus and horn); *Cervus*, sp. ? (2 metacarpals, 2 jaws, 1 tooth, 2 antlers); *Elephas*, sp. ? (part of pelvis, and tooth); *Rhinoceros etruscus* (portion of skull, r. lower jaw, astragalus, 8 upper jaw-teeth, &c.).

(2.) PLANTS, FROM THE PEATY LOAM ABOVE THE ROOTLET-BED AT PAKEFIELD AND KESSINGLAND.

Collected by Messrs. ANGELL (A), LEACH (L), and REID (R). Determined and arranged by Mr. REID.

The arrangement is that of the London Catalogue of Plants.

- Thalictrum flavum*, Linn., A. L. R.
- Ranunculus aquatilis*, Linn., L. R.
- *repens*, Linn., A. L. R.
- Nuphar luteum*, Linn., A. L. R.
- Acer campestre*, Linn., A. L. R.
- Prunus communis*, Huds., R.
- Rubus fruticosus*, Linn., A. L. R.
- Trapa natans*, Linn., A. L. R.
- Myriophyllum spicatum*, Linn., L.
- Oenanthe Lachenalii*, Gmel., R.
- Heracleum Sphondylium*, Linn., A. L. R. (previously recorded by mistake as *Peucedanum palustre*).
- Cornus sanguinea*, Linn., A. L. R.
- Bidens tripartita*, Linn., L. R.
- Picris hieracioides*, Linn., L.
- Lycopus europæus*, Linn., L.
- Atriplex patula*? Linn., A. L. R.
- Polygonum*, sp., A.
- Rumex maritimus*, Linn., R.
- , sp., L. R.
- Euphorbia amygdaloides*, Linn., A. L.
- Alnus glutinosa*, Linn., A. L. R.
- Carpinus Betulus*, Linn., A. L. R.
- Corylus Avellana*, Linn., A. L. R.
- Quercus Robur*, Linn., A. L. R.
- Ceratophyllum demersum*, Linn., A. L. R.
- Taxus baccata*, Linn., L. R.
- Sparganium ramosum*, Curtis, A. L. R.
- Potamogeton heterophyllus*, Schreb., L.
- *pectinatus*, Linn., L. R.
- *trichoides*, Cham., A. L. R.
- Zannichellia palustris*, Linn., R.
- Scirpus pauciflorus*, Lightf., A. L. R.
- *lacustris*, Linn., L.
- Carex paludosa*, Good., R.
- *remota*, Linn., L.
- *riparia*, Curtis, L.
- Brachythecium plumosum*, Swartz, L.
- Amblystegium fluitans*, Mitt., L.
- Eurynchium Swartzii*, Turn., L.

} Mosses determined by
MR. MITTEN.

Those marked R (with the Gasteropod *Bythinia tentaculata*, Linn., and the fishes *Leuciscus*, sp., and *Perca fluviatilis*, Linn.) were obtained from about five pounds of peaty loam, dug out of the base of the lacustrine deposit near the northern end of the eroded hollow close to Pakefield Lighthouse Gap, in December 1885 (see p. 24).

(3.) MOLLUSCA, FROM THE GLACIAL SANDS
(MIDDLE GLACIAL, OF WOOD).

The following list has been mostly compiled from the "Monograph of the Crag Mollusca," by S. V. WOOD (*Palæontograph. Soc.*). The species were chiefly collected by Messrs. S. V. WOOD, Junr., F. W. HARMER, and E. T. DOWSON.

The list from Billockby (from the Memoir on the Geology of the Country around Norwich, p. 95, on the authority of Mr. F. W. Harmer) is repeated here, so that the list may be as complete as possible. Billockby adjoins the parish of Ormesby St. Margaret's, but is just outside this district (in Sheet

<i>Scalaria groenlandica</i> , <i>Chemn.</i>	1 W.				
— <i>trevelyanæ</i> , <i>Leach</i> -	1 W.	2 H.			
<i>Tectura fulva</i> , <i>Müller</i> -	1 W.				
<i>Trochus cinerarius</i> , <i>Linn.</i>	1 W.				
— <i>noduliferens</i> , <i>Wood</i> -	1 W.				
— <i>ziziphinus</i> , <i>Linn.</i> -	1 ? W.				
<i>Trophon antiquus</i> , <i>Linn.</i> , var.					
<i>striatus</i> -	1 W.	2 H.	—	4 B.	— 6 B.
* <i>Trophon antiquus</i> , <i>Linn.</i> , var.					
<i>striatus contrarius</i> -	—	2 ? H.			
*— ? <i>billockbiensis</i> , <i>Wood</i>	—	2 H.			
— <i>mediglacialis</i> , <i>Wood</i> -	1 W.	2 H.			
*— <i>muricatus</i> , <i>Mont.</i> -	—	2 H.			
— <i>scalariformis</i> , <i>Gould</i> -	1 W.	2 H.			
<i>Turritella incrassata</i> , <i>J. Sow.</i>	1 W.B.	2 H.	3 B.	4 B.	— 6 B.
— <i>terebra</i> (communis), <i>Linn.</i> -	1 W.	2 H.	—	—	5 R.
<i>Voluta Lamberti</i> , <i>J. Sow.</i>	—	Serathy.			

Lamellibranchiata.

<i>Anomia ephippium</i> , <i>Linn.</i>	1 W.	2 H.			
— —, var. <i>aculeata</i> , <i>Müller</i>	1 W.				
— <i>striata</i> , <i>Broc.</i> -	1 W.				
<i>Astarte borealis</i> , <i>Chemn.</i> -	1 W.	—	—	—	6 B.
— <i>Burtini</i> , <i>La Jonk</i>	1 W.				
— <i>compressa</i> , <i>Mont.</i>	1 W.B.	2 H.	—	—	5 R.B. 6 B.
— <i>elliptica</i> , <i>Brown</i> -	—	—	—	—	5 J.
— <i>incrassata</i> , <i>Broc.</i>	1 ? W.				
— <i>Omali</i> , <i>La Jonk</i> -	1 W.	2 H.			
— <i>sulcata</i> , <i>Da Costa</i> -	1 W.	—	—	—	5 ? R.
<i>Cardita corbis</i> , <i>Phil.</i>	1 W.				
— <i>scalaris</i> , <i>Leathes</i>	1 W.				
<i>Cardium edule</i> , <i>Linn.</i> -	1 W.B.	2 H.	—	4 B.	— 6 B.
— <i>islandicum</i> , <i>Linn.</i> -	1 ? W.				
— <i>norvegicum</i> , <i>Spengler</i>	—	—	—	—	5 J.
—, sp. -	—	—	3 B.	—	5 R.
<i>Corbula contracta</i> ? <i>Say.</i>	1 W.				
— <i>striata</i> , <i>Walker and Boys</i>	1 W.	2 H.			
<i>Cyprina islandica</i> , <i>Linn.</i> -	—	2 H.	3 B.	4 B.	5 R.B. 6 B., and Wisset.
— <i>rustica</i> , <i>J. Sow.</i>	—	—	—	—	5 J.
<i>Cytherea rudis</i> , <i>Poli</i>	1 W.				
<i>Donax</i> , sp. -	—	—	—	—	6 B.
<i>Erycinella ovalis</i> , <i>Conrad</i>	1 W.				
<i>Lasæa intermedia</i> , <i>Wood</i>	1 W.				
<i>Leda lanceolata</i> , <i>J. Sow.</i> -	1 W.				
— <i>oblongoides</i> , <i>Wood</i>	1 W.	2 H.			
—, sp. -	—	—	—	—	5 R.
<i>Lima hians</i> , <i>Gmel.</i> -	1 ? W.				
* <i>Limopsis pygmæa</i> , <i>Phil.</i>	—	2 H.			
<i>Loripes divaricatus</i> , <i>Linn.</i>	1 W.				
<i>Lucina borealis</i> , <i>Linn.</i>	1 W.	2 H.			
* <i>Mactra arcuata</i> , <i>J. Sow.</i>	Bealings, W.				
— <i>ovalis</i> , <i>J. Sow.</i> -	1 W.	2 H.	—	—	6 B.
— <i>subtruncata</i> , <i>Da Costa</i>	—	—	—	—	5 J.
— <i>stultorum</i> , <i>Linn.</i>	1 ? W.				
—, sp. -	—	—	—	—	5 R.
<i>Montacuta bidentata</i> , <i>Mont.</i>	1 W.				
<i>Mya arenaria</i> , <i>Linn.</i>	1 W.	2 H.	—	—	6 B.
— <i>truncata</i> , <i>Linn.</i>	1 W.				
—, sp. -	—	—	3 B.	4 B.	5 R.B.
<i>Mytilus edulis</i> , <i>Linn.</i>	1 ? W.	2 H.			
—, sp. -	—	—	—	—	5 R.
<i>Nucula Cobboldiæ</i> , <i>J. Sow.</i>	1 W.	2 H.			
— <i>tenuis</i> , <i>Mont.</i> -	1 ? W.				
<i>Pandora inequivalvis</i> , <i>Linn.</i>	1 W.				
<i>Panopæa norvegica</i> , <i>Spengler</i>	1 W.				

<i>Pecten pusio</i> , <i>Pennant</i>	-	1 W.						
— <i>opercularis</i> , <i>Linn.</i>	-	1 W.	2 H.	—	—	—	6 B.	
— <i>varius</i> , <i>Linn.</i>	-	1 W.						
—, sp.	-	—	—	3 B.	4 B.	5 R.		
<i>Pectunculus glycymeris</i> , <i>Linn.</i>	-	1 W.	2 H.	3 B.	—	—	6 B.	7 B.
—, sp.	-	—	—	—	4 B.	5 R.		
<i>Pholas crispata</i> , <i>Linn.</i>	-	1 W.						
<i>Saxicava arctica</i> , <i>Linn.</i>	-	1 W.	2 H.					
<i>Scrobicularia plana</i> , <i>Da Costa</i>	-	1 W.	2 H.					
<i>Solen ensis</i> , <i>Linn.</i>	-	1 ? W.						
— <i>siliqua</i> , <i>Linn.</i>	-	1 ? W.						
<i>Tapes pullastra</i> , <i>Mont.</i>	-	1 W.	2 ? H.					
— <i>virgineus</i> , <i>Linn.</i>	-	1 ? W.	2 ? H.					
<i>Tellina balthica</i> , <i>Linn.</i>	-	1 W.	2 H.					
— <i>crassa</i> , <i>Penn.</i>	-	1 W.	2 H.	—	—	—	—	7 B.
— <i>lata</i> , <i>Gmel.</i>	-	1 ? W.	2 H.					
— <i>obliqua</i> , <i>G. Sow.</i>	-	—	2 H.	—	—	—	—	7 ? B.
—, sp.	-	—	—	3 B.	4 B.	5 R.	6 B.	
<i>Venus fasciata</i> , <i>Da Costa</i>	-	1 W.	2 H.					
— <i>fluctuosa</i> , <i>Gould</i>	-	1 W.						
— <i>ovata</i> , <i>Pennant</i>	-	1 W.	2 H.					
<i>Woodia digitaria</i> , <i>Linn.</i>	-	1 W.						
—, var. <i>hoptonensis</i> , <i>Wood</i>	-	1 W.						

Besides the above Mollusca, one Crustacean (*Balanus*, sp.) was got by Mr. Blake at West Caistor.

Ostracoda.

From the Glacial Sand at Corton (given as Hopton Cliff), from "A Monograph of the Post-Tertiary Entomostraca of Scotland including species from England and Ireland," by G. S. Brady, the Rev. H. W. Crosskey, and D. Robertson, pp. 103, 104. *Palaeontographical Society*, 1874.

<i>Asterope teres</i> , <i>Norman</i> .	<i>Cythere tuberculata</i> , <i>G. O. Sars</i> .
<i>Cythere albomaculata</i> , <i>Baird</i> .	— <i>villosa</i> , <i>G. O. Sars</i> .
— <i>cicatricosa</i> , <i>Reuss</i> .	<i>Cytheridea elongata</i> , <i>Brady</i> .
— <i>hoptonensis</i> , n. sp.	<i>Cytheropteron montrosiense</i> , n. sp.
— <i>latimarginata</i> , <i>Speyer</i> .	— <i>nodosum</i> , <i>Brady</i> .
— <i>macropora</i> , <i>Bosquet</i> .	<i>Cytherura nigrescens</i> , <i>Baird</i> .

The authors say that the "Ostracoda obtained from the matter submitted to us presented a general Arctic character, varied by one or two Tertiary forms, and were greatly worn."

APPENDIX IV. PORCELAIN AND POTTERY.

LOWESTOFT CHINA.

Warren House, on the Denes, half a mile E.S.E. of Gunton Church, was the site of the first manufactory of this famous porcelain. The works were carried on, as I have been informed on the spot by descendants of men who worked there, by means of a water-wheel, which was worked by a stream from the adjacent ravine. The second manufactory was on the southern side of Bell Lane, Lowestoft. The manufacture apparently lasted for about 46 years, from 1756 to 1802. Some of the ware was highly glazed, and much famed for its floral decoration. Oriental porcelain was imitated, and I have been informed that this china was sold as such; which accounts, it is said, to a certain extent, for there being no distinguishing mark on the ware, which was afterwards famed for its own intrinsic merits.

"There are many interesting specimens named and dated both in Lowestoft and Norwich. The early ware was of a very ordinary description, and the ornamentation very rudely painted, and in blue; but in their more recent manufactures they made a fine porcelain, which was painted extremely well; the intricacy of the patterns, and the minuteness of execution, entitling them to be placed in the cabinets of connoisseurs, amongst either Sevres, Dresden, or Worcester."*

The following extract from E. GILLINGWATER'S "History of Lowestoft," written in 1790, respecting the manufacture of porcelain at Gunton and Lowestoft, is, I believe, the most authentic record there is; for Gillingwater resided at Lowestoft whilst the manufactory was in existence.

"The only manufactory carried on at Lowestoft is that of making porcelain, or china-ware, where the proprietors have brought this ingenious art to a great degree of perfection, and, from the prospect it affords, promises to be attended with much success.—The origin of this manufactory is as follows":—

"In the year 1756, Hewlin Luson, esq., of Gunton hall, near Lowestoft, having discovered some fine clay, or earth, on his estate in that parish, sent a small quantity of it to one of the china manufactories near London, in view of discovering what kind of ware it was capable of producing; which, upon trial, proved to be somewhat finer than that called the Delft ware. Mr. Luson was so far encouraged by this success as to resolve upon making another experiment of the goodness of its quality upon his own premises; accordingly, he immediately procured some workmen from London, and erected, upon his estate at Gunton, a temporary kiln and furnace, and all the other apparatus necessary for the undertaking: but the manufacturers in London being apprized of his intentions, and of the excellent quality of the earth, and apprehending also, that if Mr. Luson succeeded he might rival them in their manufactory, it induced them to exercise every art in their power to render his scheme abortive; and so far tampered with the workmen he had procured that they spoiled the ware, and thereby frustrated Mr. Luson's design."

"But, notwithstanding this unhandsome treatment, the resolution of establishing a china manufactory at Lowestoft was not relinquished, but was revived again in the succeeding year by Messrs. Walker, Brown, Aldred, and Richman, who, having purchased some houses on the south side of the Bell lane, converted the same to the uses of the manufactory, by erecting

* "The East Anglian," 1863, p. 418.

a kiln and other conveniences necessary for the purpose: but, in carrying their designs into execution, they also were liable to the same inconveniences as the proprietor of the original undertaking at Gunton was; for being under the necessity of applying to the manufactories in London for workmen to conduct the business, this second attempt experienced the same misfortune as the former one, and very nearly totally ruined their designs; but the proprietors happening to discover these practises of the workmen before it was too late, they took such precautions as rendered every future attempt of this nature wholly ineffectual, and have now established the factory upon such a permanent foundation as promises great success. They have now enlarged their original plan, and by purchasing several adjoining houses, and erecting additional buildings, have made every necessary alteration requisite for the various purposes of the manufactory. They employ a considerable number of workmen, and supply with ware many of the principal towns in the adjacent counties, and keep a warehouse in London to execute the orders they receive both from the city and the adjoining towns; and have brought the manufactory to such a degree of perfection as promises to be a credit to the town, useful to the inhabitants, and beneficial to themselves.*

YARMOUTH POTTERY, &C.

"It is known that about the end of the last century a potter named Absolon had works at a place still known as "The Ovens" at Yarmouth. It appears, however, that no potting was ever done there, but that the business consisted simply in decorating ware manufactured elsewhere, and firing the colours in a gloss-kiln. The mark of 'Absolon Yarmø' is found on pieces stamped with an arrow, but it is at present uncertain to what factory the mark of the arrow should be attributed."†

* "History of Lowestoft," by Edmund Gillingwater, pp. 112, 113. See also *Art Journal*, July 1863, and "The Ceramic Art of Great Britain," by LL. JEWITT, Ed. 2, 1883, pp. 252-260, for notice of this Lowestoft China Manufacture, and p. 261 of the last for notice of Yarmouth Pottery.

† Catalogue of British Pottery and Porcelain, in the Museum of Practical Geology, London. Ed. 3, by T. REEKS and F. W. RUDLER, p. 255. See also Lowestoft Porcelain and Pottery, pp. 256, 257.

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*Names of places not in the district have * prefixed.*

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| 56. Druridge Bay. | 89. Tynemouth. | 106. Blackpool Br. |
| 63. Netherwitton. | 91. Greenhead. | 107. Allendale. |
| 64. Morpeth. | 92. Haltwhistle. | 108. Blanchland. |
| 65. Newbiggin. | 93. Haydon Bridge. | 109. Shotleyfield. |
| 72. Bedlington. | 94. Hexham. | 110. Wellhope. |
| 73. Blyth. | 95. Corbridge. | 111. Allenheads. |
| | 96. Horsley. | 112. |
| | 97. Newcastile. | |

Cumberland.

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| 55. Searns. | 65. Dockraye. | 74. Wastwater. |
| 56. Skiddaw. | 69. Bultermere. | 75. Stonethwaite Fell. |
| 63. Thackthwaite. | 70. Grange. | |
| 64. Keswick. | 71. Helvellyn. | |

Westmorland.

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| 2. Tees Head. | 12. Patterdale. | 25. Grasmere. |
| 6. Dufton Fell. | 18. Near Grasmere. | 33. Kendal. |

Yorkshire.

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| 7. Redcar. | 116. Conistone Moor. | 260. Ilonley. |
| 8. Saltburn. | 133. Kirkby Malham. | 261. Kirkburton. |
| 9. | 184. Dale End. | 262. Darton. |
| 12. Bowes. | 185. Kildwick. | 263. Hemsworth. |
| 13. Wycliffe. | 200. Keighley. | 264. Campsall. |
| 17. Guisbore. | 201. Bingley. | 272. Holmfirth. |
| 20. Lythe. | 202. Calverley. | 273. Penistone. |
| 24. Kirkby Ravens-worth. | 203. Seacroft. | 274. Burnley. |
| 25. Aldborough. | 204. Aberford. | 275. Darfield. |
| 32. Whitby. | 215. Peeke Well. | 276. Brodsworth. |
| 33. | 216. Bradford. | 281. Langwell. |
| 38. Marske. | 217. Calverley. | 282. Wortley. |
| 39. Richmond. | 218. Leeds. | 283. Wath upon Dearne. |
| 46. | 219. Kippax. | 284. Conisborough. |
| 47. Robin Hood's Bay. | 231. Halifax. | 287. Low Bradford. |
| 53. Dowholme. | 232. Birstal. | 288. Boolesfield. |
| 58. Leybourne. | 233. East Ardsley. | 289. Rotherham. |
| 62. Kidstones. | 234. Castleford. | 290. Bithwell. |
| 64. E. Witton. | 246. Huddersfield. | 293. Hallam Moors. |
| 97. Foxup. | 247. Dewsbury. | 295. Handsworth. |
| 98. Kirk Gill. | 248. Wakefield. | 296. Loughton-en-le-Morthen. |
| 99. Haden Carr. | 249. Pontefract. | 299. |
| 100. Loftthouse. | 250. Darrington. | 300. Harthill. |
| 115. Arncliffe. | | |

